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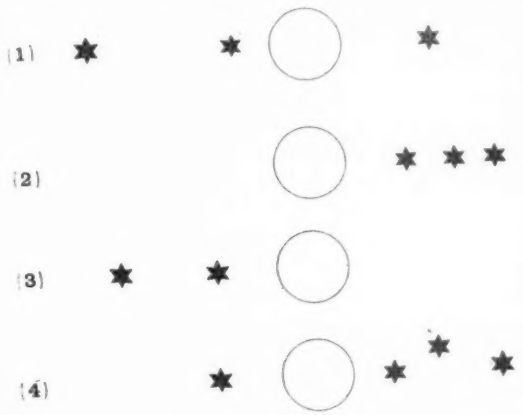
THE PLANET JUPITER.

G. W. HOUGH.

On the 7th of January 1610 Galileo casually examined Jupiter with a new telescope which he had constructed and was surprised to see three bright stars near the planet, arranged in a row, one on the right and two on the left, as in the following diagram. (1).



SATELLITES OF JUPITER AS SEEN BY GALILEO 1610.

On the next night he saw three stars all on the right side, which he thought strange, since the planet should have moved in the opposite direction. (2).

On the 10th he saw only two stars and both were on the left side. He suspected that the third was hidden by the planet and surmised that the stars were attendants on Jupiter. (3).

On the 13th of January, he finally saw four stars arranged as in the diagram, and justly concluded that the planet was attended by four moons or satellites. (4).

The configurations of the satellites of Jupiter, as given by Galileo, are of interest as being the first recorded positions of these bodies. The satellites are not visible to the naked eye, except in very rare cases.

The rays of light which are seen by most eyes about a bright star, completely obliterate the minute satellite. It is only to an abnormal eye to which the star appears as a round disc, that the visibility of a satellite is possible.

There are two or three authentic cases of persons having seen a satellite of Jupiter with the unaided eye.

When sufficient optical power is used, however, the satellites appear as round, well defined disks which may be measured with the micrometer.

The following table gives the period of revolution, distance and size of the satellites:

Satellites.	Distance Miles.	Sidereal Period.		Apparent Diameter.
		d	h	″
I	267,000	1	18.5	1.07
II	425,000	3	13.3	0.95
III	678,000	7	04.0	1.59
IV	1,193,000	16	18.1	1.39

The linear value of 1″ of arc at the mean distance of Jupiter is 2330 miles; hence satellites I and II are nearly the same size as our Moon.

The satellites in their revolution around the planet give rise to a number of interesting phenomena; viz.: eclipses, transits and occultations. When a satellite passes into the shadow cast by the planet it is eclipsed in the same way as the Moon is eclipsed by passing into the shadow of the Earth.

Very soon after their discovery it was pointed out that the eclipses might be employed for the determination of longitude, provided the time of the phenomenon could be computed for some definite meridian.

This method of getting longitude is not very exact, however, for the reason that as the satellite passes into the shadow it does not disappear instantaneously but may be seen for a considerable interval, depending on the power of the telescope used. From the observation of the eclipses, Roemer was led to the great discovery of the velocity of light in space. He found as Jupiter receded from the Earth, the eclipses occurred later and later, and finally concluded that it required 22 minutes for light to travel across the Earth's orbit.

The satellites when they pass behind the disk of the planet are said to be occulted.

The most interesting phenomena connected with these bodies are their transits across the disk of the planet. When the satellite is fully projected on the disk it may be seen as a round white spot, which gradually grows fainter as it advances farther on the disk until its light becomes of equal intensity with that of the disk itself, when it ceases to be visible. After traversing the central portion of the disk it again becomes visible, before leaving the disk on the opposite side.

With the 18½-inch refractor of the Dearborn Observatory, the satellite may be followed one-fourth of the distance across the disk before it ceases to be visible, and when the passage occurs near the poles of the planet it may be seen during the whole transit. Occasionally the satellites in transit are seen as dark spots during the entire passage across the disk. This appearance is supposed to be due to dark patches on the satellite, or in other words the side of the satellite turned towards the Earth reflects less light than the planet itself.

The satellite casts a shadow which is seen to cross the disk as an oval black spot. The shadow is not quite round because it is projected on a surface inclined to the line of sight.

Near the time of opposition a satellite and its shadow are in close proximity; at other times the satellite precedes or follows the shadow by a greater or less interval.

Occasionally stars bright enough to be observed are occulted by the planet. A number of such phenomena have been recorded.

On the 21st of March 1860 the writer, observing with the 12-inch refractor of the Cincinnati Observatory, witnessed an expected emersion of a 9th magnitude star, and also an occultation of the same star by the first satellite. In passing behind the satellite the star remained invisible for eight minutes. (Brunnow's Astronomical Notices, No. 17).

From the changes in brightness in different parts of their orbits, Sir Wm. Herschel concluded that the satellites revolved on their axes in the same time that they made a revolution around the planet.

For more than two and a half centuries the four moons of Jupiter were supposed to be the only attendants on that body; but on the 9th of Sept., 1892, Professor E. E. Barnard, with the 36-inch telescope of the Lick Observatory, detected a very faint star near the planet, which subsequently proved to be a fifth satellite. This body is exceedingly small and faint and can only be seen with the largest telescopes.

After the announcement of its discovery by Professor Barnard and before the correct period of revolution had been ascertained, the writer saw it on two nights with the 18½ in.; and so far as is known this is the smallest aperture with which it hitherto has been seen.

Jupiter is a conspicuous object to the naked eye; being brighter than Mars or Saturn but not quite equal to Venus. Under favorable conditions it may be seen during daylight when ths Sun is yet above the horizon.

The planet revolves around the Sun in a period of 11¾ years at a mean distance of 5.2 times that of the Earth from the Sun. At his nearest approach to the Earth, at opposition, his distance is about 400 millions of miles. On account, however, of the ellipticity of the orbits of the two planets, this distance may vary to the extent of 25 millions of miles.

The disk of the planet as seen in the telescope is distinctly oval, the largest diameter of the ellipse coinciding with the planet's equator. The mean diameter is about 87,000 miles and the equatorial diameter 90,000 miles.

The telescopes of Galileo were not of sufficient power to show markings on the disk; but in 1630 Zucchi saw that the disk was crossed by dark belts which were arranged parallel to the equator of the planet. The belts of Jupiter have been observed by all subsequent astronomers and are a permanent feature of the visible phenomena seen on the disk.

The equatorial belt is frequently mottled with white spots and markings, presenting a variety of detail very difficult to delineate. Besides the great belts which are always visible, there are fainter streaks, which are parallel to the equator and sometimes may be seen as far as 45 degrees of north and south latitude. Usually beyond 45 degrees of Jovian latitude, there is a fine shading extending to the poles. Besides the belts, small oval white spots, 2,000 to 3,000 miles in diameter, are visible at every opposition in latitude 30° to 40° south and occasionally also on the north side of the equator.

The most conspicuous spot of recent years is known as the great red spot of 1878. This object was of a reddish brick color of oval form, 30,000 miles in length and 8,000 miles in breadth, and was situated 19 degrees south of the planet's equator.

In the year 1665 Cassini observed a great spot near the margin of the southern equatorial belt. This object was observed by astronomers from 1665 to 1713, during which period it vanished and reappeared nine times, and on no occasion was the spot visible continuously for more than three years.

In 1860, Mr. Baxendall, of Manchester, England, published a drawing of Jupiter showing a depression in the south edge of the equatorial belt similar to the one found in recent years north of the great red spot.

In 1869-70 a number of observers delineated an oval spot south of the equatorial belt. As the great red-spot of 1878 has been visible, during a whole revolution of Jupiter around the Sun, although at times so faint as to be seen with greatest difficulty, I

think we are justified in considering it a permanent feature. Its change in distinctness is probably due to its greater or less submergence in the gaseous medium in which it floats. I think it highly probable that the great spot observed by Cassini in 1665 and also the spots of 1860-69, 70-78 are all identical.

The minute history of this remarkable object, from 1878 to the present time, is beyond the scope of the present article. It may be stated, however, that the spot is not fixed, but it has been subject to a considerable drift in longitude and a slight shifting in latitude. The rotation time of the planet from observations of this spot in 1879 was $9^h\ 55^m\ 32^s.2$, while during the past few years the rotation period has increased to $9^h\ 55^m\ 40^s$ to 41^s. The spot has maintained essentially the same size and shape during the past fourteen years that it has been observed by the writer.

As to its physical constitution we have no definite knowledge. During the years 1879 to 1883 the spot was of a decided reddish-brick color; but of late years it has been very much paler, and at times practically invisible. Assuming that the spot has a depth equal to its breadth, its volume would be about three times that of the Earth.

The mean density of Jupiter is 1.37 times that of water and hence the surface density is probably only one-third as great or 0.46, which would indicate a medium less dense than any known liquid.

As the great red-spot shifts its position we infer that it floats in a medium which has a depth of at least 8,000 miles. From the observations of the transit of a satellite and also the shadow of a satellite over the red-spot it is inferred that the spot reflects less light than the disk. The great red-spot, the equatorial belt and other dark marking are probably of similar constitution.

If the planet is yet hot, as is often stated in recent works, the dark markings might be regarded as matter at a lower temperature than the rest of the surface.

The transits of satellites across the disk, however, proves conclusively that the central part of the disk of the planet reflects the same amount of light as the satellites and hence is not hot enough to have any inherent light of its own.

In the equatorial region, round white spots are seen at every opposition which have a drift of 250 miles per hour in the direction of the planet's rotation, corresponding to a rotation period of $9^h\ 50^m$. These spots are sometimes maintained with slight change of outline for a number of years as was the case with two spots observed from 1879 to 1882.

As the axis of Jupiter is almost perpendicular to his orbit, the climate would be nearly constant during the whole Jovian year. It would be hot at the equator and cold at the poles.

This condition of climate offers an explanation of the greater changes taking place in the equatorial regions than in higher latitudes.

From the motions observed in both the white and dark spots, it is inferred that everything we see is floating in a medium, having a depth measured by thousands of miles. That this medium is not atmospheric, as the term is usually understood, is apparent from two reasons.

1st. The displacement in the great volumes of matter, is usually slow.

2d. The atmosphere cannot be of any considerable depth, as compared with the diameter of the planet, because the edges of the disk present a sharp smooth outline. That there is an atmosphere overlying the denser medium is highly probable. This true atmosphere might subtend an angle of 1″ of arc or 2,000 miles, without seriously affecting the definition of the limbs of the planet as seen through the telescope. The equatorial white spots and other matter, which has a drift of 250 miles per hour, for mechanical reasons, must be located in the outer region of the planet's envelope.

The two principal rotation periods $9^h\ 50^m$ and $9^h\ 56^m$ are best accounted for by supposing that the whole outer layer of the planet's envelope, situated within 20° of the equator, moves in the direction of the planet's rotation with a velocity sufficient to complete a revolution around the planet in 45 days. All matter either white or dark situated in this envelope would be carried with it.

The period $9^h\ 56^m$ given by the great red spot, the equatorial belt and oval white spots distant from the equator, would be due to objects situated at a lower level in the gaseous medium.

July 3, 1880, shows the second satellite in transit over the great red spot. When the satellite touched the red spot it formed a notch, and when fully projected on the spot it appeared as white as when outside the disk of the planet.

A white spot near the equator, which was visible for a number of years.

The absence of belts or shadings, especially on the upper part of the disk, is due to the fact that the planet, at that time was too far from the Earth.

Nov. 1, 1880, shows the shadow of the first satellite on the

disk, and the shadow of the second satellite projected on the red spot. The shadow on the red spot was not quite as black as the shadow on the disk. Two dusky spots are shown in belt No. 3.

Oct. 10, 1881, shows the great red spot and a peculiar spur under it, which was first seen by the writer on Sept. 9, 1880. Also a minute black spot in the north polar region, and two oval white spots south of the great red spot.

April 5, 1884, shows the belt system, the great red spot, group of white spots south, three very minute white spots on the equatorial belt and three dusky patches on belt No. 2.

It shows also, when compared with the previous sketches, very plainly the widening of the equatorial belt on the south margin.

During the past fourteen years, the equatorial belt and the great red spot did at no time come in contact. Although the belt drifted as far south as the center of the red spot yet they remained separate.

The belt south of the red spot also moved north, but at no time was the spot actually in contact with it. May 2, 1886 shows the ring form of the great red spot, small white spots south, which are seen at every opposition, the equatorial belt, the fainter belts and the shadow of the second satellite.

The ring form of the great red spot was first seen by the writer on Feb. 27 1885, and this form continued with greater or less distinctness during the opposition of 1887.

DEARBORN OBSERVATORY, Northwestern University,
Nov. 8, 1894.

THE GREAT PHOTOGRAPHIC NEBULA OF ORION, ENCIRCLING THE BELT AND THETA NEBULA.

E. E. BARNARD.

Experiments With a Very Small Lens in Photographing Very Large Nebulæ, etc.

I have recently been experimenting with a small short-focus lens. Some of the results are very interesting.

This lens belongs to a cheap (oil) projecting latern and is 1½ inch in diameter and 3½ inches focus (from the rear lens). It gives a field of about 30°, only one-half of which, however, is at all flat—but on this portion the stars are fairly good. The scale is about 10°.3 to the inch.

The ratio of the aperture to the focal length is 1 : 2.3 while that of the Willard lens is 1 : 5.

This large light ratio makes the lens very suitable for certain work where the smallness of the scale is not objectionable—or is really desired,—such for instance as very large diffused nebulosities, large comets, the Milky Way, etc. It will doubtless be also admirably suited for photographing meteors—catching from its great light ratio and large field many meteors that would be entirely missed by such telescopes as the Willard lens.

So far I have made nearly 20 photographs with this lens, which for identification I shall call the "lantern lens."

These exposures range from one second up to four hours.

On account of this light ratio the diffused light of the stars scattered over the sky also photographs, so that very prolonged exposures are only possible with it when the sky is free from milkiness—or whiteness. Its penetrating power is not far from that of our Willard lens.

When the moon is very young, the dark or earthlit portion can be photographed with it in from 1 second to 3 seconds.

The cloud forms of the Milky Way, such as those in the region of M11, are well shown in from 10 to 15 minutes.

An exposure of one hour showed all the great mass of nebulosity near Alpha Cygni, and doubtless 15 or 20 minutes would show it clearly.

One hour showed the full extent of the great Andromeda nebula, and I have no doubt but that it could as well be shown with far less than half that time.

Four hours' exposure was given on the region about the Pleiades. Besides showing the nebulosities of the cluster it showed also the large diffused nebula N. G. C. 1497. This nebula, which was discovered by me with the 6-inch Cooke equatorial of the Vanderbilt University, Nashville, Tenn., on Nov. 3, 1885, was photographed by Dr. Archenhold in October, 1891 (See *A. N.* 3082). I have a fine photograph of it with the Willard lens with three hours' exposure, and of which I shall have more to say in a later paper. The impression with the lantern lens is very strong and does not materially differ (except in point of size) from that with the Willard lens. The nebula is a very singular object, however, and well worth study. It is somewhat over 2° long and seems to be quite complicated in structure.

Probably an exposure of less than half an hour would show this object with the lantern lens. By the way, Dr. Archenhold is wrong in speaking of this object as having been discovered by

PLATE XIV.

THE GREAT PHOTOGRAPHIC NEBULA IN ORION.

photography. Visually, on account of its very diffused nature, it is a very faint object in any telescope.

The most interesting, however, of these lantern lens pictures, are two of the constellation of Orion (for it takes in nearly the entire constellation).

These were made 1894, Oct. 3 and Oct. 24, with 2 hours', and 1 hour 15 minutes' exposure, respectively.

To my surprise these pictures showed an enormous curved nebulosity encircling the belt and the great nebula, and covering a large portion of the body of the giant. A description of this nebula would not only be complicated but it would fail, also, to give any impression of its form and magnitude; I have, therefore, made the enclosed drawing of it which will show at once its exact location and form. The drawing is on nearly twice the scale of the original negative and the stars are taken from Proctor's Chart.

After I had made this drawing and partly written this paper, I remembered having seen somewhere that Professor W. H. Pickering had once spoken of a great nebula shown on his photographs of Orion and previously unknown. I have looked up his paper on the subject and find it in the *Sidereal Messenger* for January, 1890 (vol. 9, p. 2). I will quote here what Professor Pickering has to say concerning this remarkable object:

"An interesting structure brought out upon our plates is a large spiral nebula whose outer extremity starts in the vicinity of γ Orionis. It passes about four degrees north of ζ, extends to γ thence to β, then north to η, with an outside stream lying nearly north and south, and preceding β about four degrees. Another stream lying nearly east and west precedes η about the same amount. This nebula is about seventeen degrees in length, by nearly the same in breadth, and surrounds a cluster of bright stars including the belt and sword handle, and extending towards γ. The region containing the nebula is noticeably lacking in stars brighter than the eighth magnitude, but contains the very bright stars γ and β. It is possible that a plate with double our present exposures, which we are soon going to try, will fill the space between η and ζ, thus making the great nebula the inner termination of the spiral. This nebula is shown by three different exposures and is very distinctly marked."

Professor Pickering's photographs were made at Wilson's Peak in southern California (altitude 6250 feet) with a Voightländer portrait lens of 2.6 inches aperture and 8.6 inches equivalent focus, with an exposure of three hours. Stars from the 11th to the 12th magnitude were well shown.

In the present pictures the shorter exposure shows the nebula best; this was perhaps due to a darker sky.

On my drawing, I have marked a portion of the nebulosity, from 1° to 2° east of Tau, with dots, as it is so feeble at this point that I cannot be certain of it. Two other portions, very slightly uncertain, I have also marked with dots; these, however, I am confident exist on the negatives. The rest of the nebula is well shown. It is brightest near 56 and 60 Orionis. Its extreme diameter is about 14° or 15°. Compared with this enormous nebula the old θ, or so-called "great nebula," is but a pigmy.

That this object shown on my plates is the same photographed by Professor Pickering in 1889 there is no doubt, as will readily be seen upon comparing his description with my drawing. The present photographs therefore, fully confirm the pictures of 1889. This confimation is all the more valuable as it was unconsciously and independently made.

MT. HAMILTON, 1894, Oct. 27.

MARS.

PERCIVAL LOWELL.

ATMOSPHERE.

Man generously furnished Mars with an atmosphere without waiting to learn whether nature had done so or not, much as the same thoughtful donor provided him beforehand with a brace of moons; such appurtenances seeming part of any properly constructed planet. The one gift appears to have been more thoroughly sanctioned than the other. For the moons when finally seen accorded admirably with their myths; while the atmosphere, from our purely local standpoint leaves something to be desired—more of it chiefly.

Vital, indeed, not only to life on a planet but to the very life of the planet itself, if we define life broadly as a chain of changes, atmosphere is. Without it change would soon come to a standstill for want of means to work with. So soon as that was friable had crumbled to pieces under the Sun's fierce heating of the surface, change would stop and the planet roll a mummy world through space, like our own ghastly attendant, the Moon.

This fact alone suffices to show that Mars possesses an atmosphere. Effectively enough, the very first change detected on the

planet's disk, the phenomena of the polar snows, emphasizes the deduction with special cogency. For the yearly locking and unlocking of this mass of water turns directly to atmosphere for key. Were Mars destitute of air, the snow-cap once metled to water would flow to the equator and know no return again to the pole. That every year the snow-cap reappears with clock-like regularity shows that a Martian atmosphere exists.

Reasoning on the polar snows, therefore, suffices of itself to prove an atmosphere. Further reasoning furnishes us with some probabilities as to its character.

Suppose to start with that, at the time of its generation by fission from the parent Sun, each planet took with it as a birthright its share of chemical constituents,—that is that each had the same proportion of hydrogen, oxygen and so forth; the amount of each substance being in direct ratio to the planet's mass. Now as the planet cooled the denser materials would go to form the nucleus leaving the lighter as outer envelopes; a result which would occur whether the planet were big or little. But though the strata would be similarly disposed in both, the pressure due to gravity would be less everywhere in the lesser body. Its relative density would be diminished and its relative volume increased. The smaller the planet the greater its volume, therefore, for its mass. Consequently its outer gases would have to cover relatively more space and grow thin in endeavor to do so. This is cause number one why a smaller planet should have a thinner atmosphere.

Cause number two is a mathematical consequence of space. Of two spheres—or other similar bodies—of different sizes, the smaller has the more surface for its volume. For volume being a quantity of three dimensions while surface is one of two, as the dimensions decrease the volume shrinks faster than the superficial area. For example, if one sphere be of half the diameter of another, it has one-eighth the volume of the first but one-quarter the surface. Therefore in the case of the second body an equal volume of air has to spread over twice the space; and this double duty in addition to the one above.

Cause number three consists in the fact that gravity being directly proportionate to mass, a thing of three dimensions, and inversely proportionate to the square of the distance, a thing of only two, is relatively less on the surface of the lesser body. Consequently the atmosphere being there less attracted must extend to a greater height and is of course still further thinned out.

Now in addition to these three ways in which mathematics and

molar physics combine to deprive a small body of the benefit of what air it has by spreading that air out, a fourth cause, from molecular physics, would actually take some of that already scant air away. This ingenious application of the properties of molecules to planetary despoiling of the weak, is due to an Irish gentleman whose name for the moment escapes me; and facts appear to support it.

The molecular theory supposes gases to be made up of myriads of molecules in incessant motion to and fro of a very rapid kind, those of oxygen travelling on the average about fifteen miles a minute, those of aqueous vapor about twenty miles in the same time, while those of hydrogen, the fastest known, dart about commonly at a speed of a mile a second. This is their average velocity but by collisions among themselves the average speed may be increased something like seven fold. Sooner or later each molecule is bound to attain this maximum velocity of its kind—seven miles a second for a molecule of hydrogen, between two and three miles a second for one of oxygen or aqueous vapor.

Now if a body, whether a molecule or a cannon ball, be projected away from the Earth, the Earth will instantly try to pull it back again—which instinctive holding of mother Earth to what she has, we call gravity. In the cases with which we are familiar her endeavor is successful. But the greater the velocity which the body has at starting, the longer will it take the Earth to overcome it and compel the body to return. As the velocity of departure is increased finally one is reached which the Earth is just able to counteract. This velocity is that which the Earth would generate in a body falling to it from infinite space; since it is able to destroy on the way up just the motion it can generate on the way down. A greater velocity than this it could never wholly overcome and a body starting at that speed would leave the Earth never to return. This critical velocity differs for different planets, dependent on their masses and sizes, being greater in the larger. In the case of the Earth it is between six and seven miles a second. Any body starting from its surface at that rate would leave it forever.

Now the molecules of hydrogen, as we have seen, attain at times a speed surpassing this. If therefore free hydrogen were present on the Earth's surface and encountered no chemical attraction to hinder it, as each molecule attained its maximum speed it would bid the Earth good-bye and start on hyperbolic travels of its own through space. That it shall reach its maximum speed is all that is necessary to this end, the direction of

its motion, whether directly away from the Earth or tangential to it or in any direction between the two, being immaterial to the matter; the direction merely affecting the form of the orbit. To each molecule in turn must come this happy release; till the Earth stood deprived of hydrogen gas. Now it is a significant fact that there is no free hydrogen present in the Earth's atmosphere.

The maximum speed attainable by the molecules of oxygen or aqueous vapor being respectively about 1¾ and 2⅓ miles per second, never reach the critical velocity and therefore must remain earth-bound. And the earth's atmosphere contains as a matter of fact plenty of free oxygen and aqueous vapor.

The other planets appear to confirm this deduction. For the moon the critical velocity is so small that any gas can leave it and in consequence all have done so. The moon has no perceptible atmosphere. Whatever its attraction for lovers, no gas is sufficently attracted by it to stay.

On the other hand the giant planets give evidence of very dense atmospheres. They have kept all they ever had.

But the most striking confirmation of the theory comes from a comparison of the cusps of Venus and Mercury. Atmosphere would by its refraction of the solar light prolong a cresent planet's cusps beyond their true limits. Length of cusp becomes therefore a criterion of the presence of atmosphere. Now in this respect there is a noticeable difference between Venus and Mercury. Venus' cusps are prolonged beyond the semi-circle; Mercury's are not.

With Mars the critical speed is about three miles a second; just enough for him to be able to hold on to his oxygen and water-vapor, to say nothing of carbonic acid gas which is still easier to control; all those gases, in short, which are essential to life.

In the above four ways, then, theory helps to give us the probable character and constitution of the Martian atmosphere. Now let us see what observation has to say on the subject.

Observation, so far as it goes, confirms these deductions; but its confirmation is chiefly of a negative character. For the observed annual change in the polar snows is about the only proof positive of the presence of an atmosphere that observation affords. Fortunately this suffices to establish its existence; and the negative character of the rest of the evidence further goes to show that, as deduction makes it, that atmosphere is thin.

This observational evidence is, indeed, more negative than is commonly believed. We read in many books on astronomy of

observations of clouds and mist obscuring at times portions of the planet's surface; observations circumstantially told and interestingly developed. But such are, in all probability, mistakes. The evidence against them is both direct and inferential. The better the character of the observations the less such phenomena appear.

The only undoubted obscuration is what occurs upon the planet's limb. Along the limb extends a fringe of light that swamps all detail in its glare; a phenomenon which has been noted for many years and been generally attributed to mist. The light is either in the form of a lune, tapering to nothing at the ends of the phase axis and extending about thirty degress in at the middle, or it is a ring of light completely girdling the disk. The former effect occurs when Mars is gibbous; the latter when he is full. The effect has been credited to morning or evening mists, since at or near opposition the limbs correspond to the sunrise and sunset hours on Mars. Some observers have even noted a persistent difference in illumination between the two. Now leaving aside for the moment the fact that only at the very instant of opposition is the illumination of the two limbs strictly comparable since at all other times the one is of necessity less illuminated than the other—different observers have unfortunately come to diametrically opposite conclusions, some asserting the sunrise limb to be the more misty, some the sunset one. Meanwhile the latest observations seem to prove that neither morning nor evening mists are the cause of the phenomenon. For in June last the limb-light was steadily very conspicuous and extended in about thirty degrees from the limb. Mars was then gibbous and the limb stood, the middle of it, at nine o'clock of a Martian morning. The limb-light, therefore, extended to eleven o'clock in the day. But at opposition this is very nearly the centre of the the disk and the only difference to a terrestrial observer from his position would be that the thickness of the mist would increase by the secant of the angle of the point from his meridian. At opposition, therefore, the obscuration should be two-fifths as great for the eleven o'clock meridian as it was in June. Yet at opposition that part of the disk is perfectly clear.

Our Moon offers an instructive parallel to this effect. For the like limb-light is visible along her limb, in shape and brightness strikingly analogous to that of Mars. Now the Moon has practically no atmosphere.

Although no obscuration of the central portions of the disk seem to occur, certain bright patches have been observed on Mars

and have been called cloud. Now these patches do not move, and what is more show regularly on special parts of the planet's surface, so far as it has been possible to observe them, but with differing intensities at different times. Such are the regions known as Elysium, Tempe, Eridania, Memnomia and Ophir, together with several smaller ones.

Now, without here taking up the arguments in favor of their being simply land of a specially desert type, there are reasons which render it unlikely that they are cloud. That they do not change their position may be met by the supposition that they are not ordinary clouds but more or less permanent cloud-caps upon mountain peaks. For the regions thus brilliant are apparently never crossed by canals and may therefore well be high. But the height of the Martian mountains seems a fatal objection to this theory. For in the first place observation tends to show that the mountains of Mars are low affairs scarcely worthy the name. Secondly owing to the thinness of the air at the surface of the planet and its relatively less rapid thinning out on ascent, the Martian mountains would not only have to be as high but vastly higher than the terrestrial ones for condensation to cap them with cloud.

But, though the evidence is as yet insufficient to prove the existence of cloud or mist on Mars, of water-vapor as such present in his atmosphere there is practically no doubt whatever. It is through the air that the water liberated every year from about the pole must return to form the next winter's snows. Furthermore the spectroscope has been thought to show the lines of water-vapor in the spectrum of Mars but the observation is of extreme faintness and the result proportionately doubtful. But another argument from the behavior of the polar snows can be drawn with some cogency. From the manner and extent of their melting, the climate of Mars seems peculiarly mild whereas the thin air and the distance of the planet from the Sun would necessitate an unpleasantly frigid one, something almost perpetually below the freezing point. Now, as Flammarion points out, the presence of sufficient water vapor in the air would suffice to produce the observed convenient amelioration.

To sum up then our present knowledge of the atmosphere of Mars, we may say that we have proof of its existence and reason to believe that it is at the surface of the planet about half as thin as ours is on the summits of the Himalayas; that in constitution it is probably similar to our own except that it is more heavily charged with water-vapor; that it is nearly if not quite cloudless

and that rain or snow are almost unknown phenomena on Mars, dew or hoar frost ill supplying their place. For precipitation would be actually too precipitate for anything else. Finally that in the day-time at least, it is almost perpetually fine weather on Mars.

One deduction from the extreme rarity of the air we must, however, be careful not to make: that because it is thin, it is incapable of supporting intelligent life. That beings physically constituted like us could not exist there, with any comfort to themselves, is more than likely. But lungs are not inseparably linked to logical powers, as we are sometimes shown in other ways, and there is nothing in the world or beyond it that we know of to hint that a being with gills might not be a superior person notwithstanding. Doubtless a fish who had had no experience of man would conclude life out of water to be impossible. In the same way to argue intelligent life beyond the pale of possibility because of less air to breath than that to which we are, locally, accustomed is, as Flammarion happily puts it, to argue not as a philosopher but as a fish.

LOWELL OBSERVATORY, Nov. 5th 1894.

ON THE VARIABLE STARS OF SHORT PERIOD.

P. S. YENDELL.

Among the amateurs now interesting themselves in the observation of the variable stars, it would be gratifying to see one or more taking up the watch on those of the class known as short-period stars, that is to say, those periodic variables, the cycle of whose light-changes is completed in a space of not more than a month. There seems to be an impression that these stars are all extremely difficult of observation; this is not the fact, and the amateur can hardly adopt a more useful line of work, than to take up the observation of some of the stars of this class. So far as is known to me, I have been for some years past almost the only observer that has made a practice of keeping a watch on them, and it is very desirable that others should take up the lines of observation which are being crowded out from my own list by the pressure of other work of greater importance.

While, as above intimated, the work is not of essentially greater difficulty than the observation of variables of long period, it also furnishes the best training-school to fit the observer for work

upon the stars of the Algol type, the line of observation which more than any other calls for the practiced eye and mind that come only with experience.

The variables of this class now known are, with only three exceptions easy objects for the field and opera-glass; they present no difficulty in identification, being nearly all specially designated on the naked-eye star-charts; and their evident changes from night to night, make them very interesting objects to study.

The general rules laid down for the observation of the long-period variables are in every respect applicable to these stars; with the exception, that when the period is of less length than a week the graphic method of determining the maxima and minima is seldom applicable to good purpose. In the cases of these stars, these points have oftenest to be deduced by the use of a mean light curve; that is to say, the curve found by reducing a long series of observations to one epoch, and drawing a curve to satisfy the normal or mean light values obtained from groups of observations, each group covering a definite portion of the time of variation. The beginner is advised not to attempt to form such curves for himself, but to use those already published by observers of known experience, as the early curves made by himself from short series of observations will not be valuable. The process of using the mean light curve will be exemplified further on.

The cautions with regard to the influence of atmospheric absorption and changing hour-angle, given by the present writer in his paper in this periodical, Vol. II, p. 16, are especially applicable to these stars, as the comparison stars are in most cases at angular distances sufficient to render the effects due to these causes very perceptible. The best precautions against the errors arising from these influences are, in the first instance, to avoid observing near the horizon, or, if this is impracticable, to use when possible only those comparison stars at or near the same altitude as the variable; and when this cannot be done to multiply comparisons so as to diminish the effects due to this cause.

In the second case, to estimate the difference between the two stars by looking at them alternately, and *not* to compare them at the same glance.

At the present time there are eighteen stars known to belong to this class, as follows:

	R. A.			Decl.		m	m	d
2279 T Monocerotis	6	19	49	+ 7	8.4	{5.8 — 7.4} {6.4 — 8.3}		27.00
2375 S Monocerotis	6	35	28	+ 9	59.3	4.9 —	5.4	3.44
2509 ζ Geminorum	6	58	11	+ 20	43.0	3.7 —	4.5	10.15
4805 W Virginus	13	20	52	− 2	51.5	{8.7 — 9.8} {9.2 — 10.4}		17.25
5952 Y Herculis	16	32	0	+ 7	18.6	6.9 —	8.0	20.5
6368 X Sagittarii	17	41	16	− 27	47.6	4 —	6	7.01
6404 Y Ophiuchi	17	47	17	− 6	7.1	6.2 —	7.0	17.13
6472 W Sagittarii	17	58	38	− 29	35.1	4.8 —	5.8	7.89
6573 Y Sagittarii	18	15	30	− 18	54.3	5.8 —	6.6	5.77
6636 U Sagittarii	18	26	0	− 19	11.7	7.0 —	8.3	6.74
6758 β Lyræ	18	46	23	+ 33	14.8	3.4 —	4.5	12.91
6984 U Aquilæ	19	23	58	− 7	15.0	6.4 —	7.1	7.03
7124 η Aquilæ	19	47	23	+ 0	44.9	3.5 —	4.7	7.17
7149 S Sagittarii	19	51	29	+ 16	22.2	5.6 —	6.4	8.38
7437 X Cygni	20	39	29	+ 35	13.6	6.4 —	{7.2} {7.7}	16.39
7483 T Vulpeculæ	20	47	13	+ 27	52.5	5.5 —	6.5	4.44
8073 δ Cephei	22	25	27	+ 57	54.2	3.7 —	4.9	5.37
8116 W Cephei	23	7	22	+ 59	8.4	7.3 —	8.3	6.2

The numbers in the first column are those of Chandler; the positions are for the equinox of 1900; the fifth and sixth columns give the limits of variation in magnitude; and the last column, the approximate period.

The elements of variation of each star will be given in the description to be given of each.

Of the above list, Y Herculis, W Virginis and W Cephei are too difficult for the beginner, and will be omitted in dealing with the stars individually, as well as S Mononcerotis, which is also a very difficult star, the evidence of whose periodicity, to say the least, rests on the testimony of Winnecke alone, and which is to be subjected to a careful and critical scrutiny during the coming season, to clear up the uncertainties respecting its variation.

The variations of the stars of this class are exceedingly regular, and so far as is now certainly known, none of them shows any periodical irregularity, though several of them have at one time or another been suspected of doing so; there is still a slight uncertainty in one or two cases, but evidence is as yet wanting to prove or disprove the fact.

The greater number of the stars under consideration belong to what is commonly known as the Eta Aquilæ type, from the star in which their characteristic course of variation was first noticed; in stars of this type the increase is rapid and regular, generally occupying less than half the period of variation, while the decrease is slower, and in some cases not of uniform rapidity.

Beta Lyræ and S Sagittæ show peculiar types of curve, the former having two nearly equal maxima and two unequal min-

ima, while the latter, according to my observations, has two equal maxima, separated by a slight depression, not amounting to a minimum.

Although many of these stars can be well observed with the naked eye some observers prefer to use the opera-glass upon them, for the reason that the observations can thereby be carried without a break through the monthly period of bright moonlight; some of them need the field-glass, and two or three, being either too faint or in too crowded regions for the latter to deal with them, are to be successfully observed only with the telescope. It may be well here to caution the beginner to use no more optical aid than will enable him to make his observations with ease and certainty, as, when the images are either too bright or too faint, comparisons are difficult and uncertain, and too much light-collecting power is for this work as bad as too little.

Before taking up the individual stars, it remains to explain the manner of making use of the mean light-curve. This is done in the following manner: as a preliminary step to the work of making the determinations, it is convenient to plot the entire series of observations to any convenient scale, so that a glance will commonly show the relation of each observation to the nearest maximum or minimum. The observations above a certain selected value, about midway of the star's light-range, are used to determine the times of maxima, those below this point for the minima.

The indicated interval between each observed step-value and the nearest maximum or minimum is then found by interpolation from the star's light-table (an example of which will be given later on in this article); and the value of this interval being algebraically added to the time of observations, gives the time of maximum or minimum indicated by that observation; and the arithmetical mean of the indicated times of each group is taken as the indicated time of the phase, to which a weight is assigned proportional to the number of observations from which it is deduced.

We will take for an example four of my present season's observations of 7438 T Vulpeculæ: the individual dates are:

1894, Sept. 21.323	5.6	wt. 1
22.330	1.9	1
23.430	10.3	½
24.351	6.6	1

The observations are reduced to the step-values shown, by the scale which will be published with the other particulars about this star, in its turn; and the following reductions are made by

using my own mean light-curve, which will be found in the same place.

The light-range indicated by this curve being from 1.94 at minimum to 9.78 at maximum, the step-values below 5.9 will be used for the determination of minima, and those above it for the maxima.

A glance at the reduced step-values shows that one maximum and one minimum are indicated by these observations.

Taking the observations in order, we have first that of Sept. 21, 5.6. This being below the limit 5.9, will be used to determine the minimum following it. Looking at the readings in the light-table, we find by a simple interpolation, that this light is reached at 2.09 days before the minimum, and that therefore the time of the minimum phase indicated by this observation is Sept. 21.323 $+{}^{d}2.09 = 23.413$; the light-value for Sept. 22 is 1.90, almost exactly the mean minimum light, so we let the date of observation stand as that of indicated minimum, and taking the mean of the two dates, we have Sept. 22.872 as the indicated date of minimum, to which we assign a weight of 1.

Next we come to the observation of Sept. 23, 10.3; this being half a step above the mean maximum light, we let stand as indicating a maximum at the time of observation, giving it half weight, as depending on a single comparison; on the 24th, we find the observed light at 6.6; this is on the maximum side of the dividing limit, and as a maximum is indicated by the preceding night's observation, we look for it in the light-table, after the maximum; we find it to indicate the maximum as passed $0^{d}.767$ previous to the time of observation, or Sept. $24.351 - 0^{d}.767$, = Sept. 23.584, and this indication, as afforded by two comparisons, with stars both brighter and fainter than the variable, is given full weight: so we have, as the weighted mean of the two indications, Sept. 23.533, the indicated time of maximum, to which we give full weight like the other.

In the following papers, each star will be taken up in the order of its right ascension, and sufficient data given to enable the beginner to take up the observation of the star without difficulty, with a short history of the star. The stars 2375, 4805, 5952, and 8116 will be omitted from these papers, as being for various reasons, unfit subjects for a beginner in this class of work.

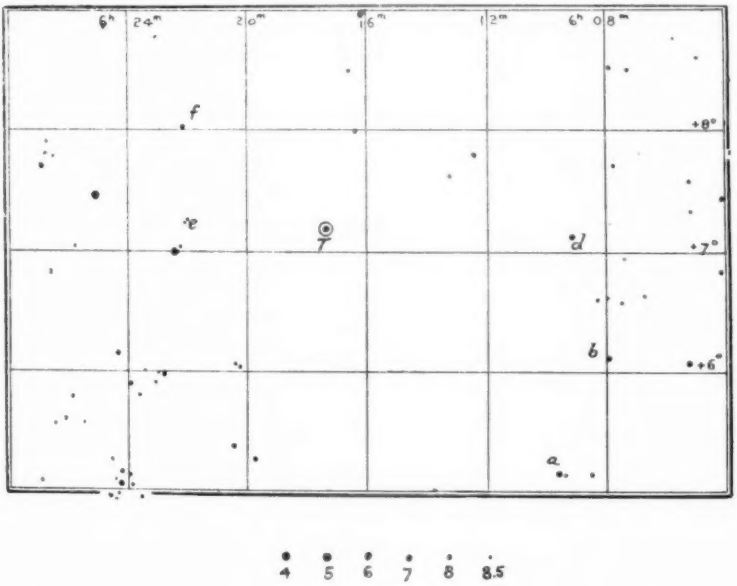
In case of any difficulty occurring which is not here provided for, I shall be glad to hear directly from the observer, and invite correspondence on the subject.

All the data concerning position, elements, and the limits of

variation, in the following descriptions, are taken from Chandler's Second Catalogue of Variable Stars, which brings our knowledge of the subject down to the date of its publication.

The authorities from which the charts are taken, and those for magnitudes and mean light-curves, will be given as occasion occurs.

It will be convenient, especially in referring to well-known atlases and catalogues, to use certain abbreviations, especially in tabulation.



IDENTIFICATION CHART, FROM THE DURCHMUSTERUNG, GIVING THE STARS TO 8.5m.

The principal ones are as follows: DM stands for Argelander's Bonn Durchmusterung; SDM, its continuation by Schoenfeld, the Southern Durchmusterung; PDM, the Potsdam Photometric Catalogue; UA, Gould's Uranometria Argentina; UN, Argelander's Uranometria Nova; H, Heis' Atlas Novus Caelestis; and so on.

2769. T Monocerotis.

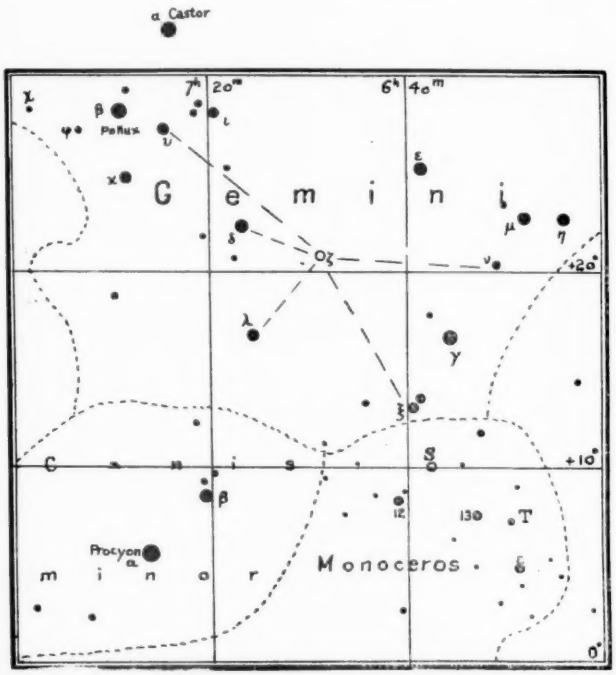
R. A., $6^h\ 19^m\ 49^s$ Dec. $+7°\ 8'.4$ (1900).

Elements of Variation.

$$\text{Max.}_{1885,\text{ April }1.81} + {}^{d}27.0037\ E.$$

Minimum precedes maximum 7.93*d*.

The variability of this star was discovered by Gould, at Cordoba, in the course of the observations made for the Uranometrio Argentina, in the year 1871. It was observed in that year and 1782 by his assistant, Davis, and by Schoenfeld from 1871 to



T Monocerotis and ζ Geminorum.

1875. From the latter year until 1884, when it was taken up by Sawyer, a gap occurs, during which there are no published observations. My own observations of the star began in 1888, and, as well as Sawyer's, have been carried through every season since.

The star is an easy one to identify and observe, though, from

the near commensurability of its period with the lunar month, the minima are from time to time difficult or impossible to observe for several successive periods. Partly, perhaps, from this latter cause, the interval from minimum to maximum, in my mean light-curve, given below, disagrees decidedly with that of Chandler's elements, above. This is of less importance, however, as, owing to the length of the star's period, the graphic method of determining the phases is almost always available.

The star can be observed with a large opera-glass, but a field-glass is better, as the minima are pretty faint.

The charts are; the general one for this star and ζ Geminorum, from Schurig; and the identification-chart, from the DM, giving the stars to 8.5m.

The comparison-stars and their magnitudes are given in the following table; the latter are taken, so far as is possible, from the PDM; those not found in that catalogue are from my own estimates from the light-scale, and are given under the heading Y. The light-scale, my own, is given in the column headed Light. The positions are from the DM.

The mean light-curve is my own, from observations up to May, 1892.

COMPARISON-STARS.

		Positions, 1855.						Magnitudes.		Light.
		R. A.			Dec.			PDM	Y	(Steps).
	°	h	m	s	°			m		
$a = +5$	1168	6	9	36.1	+5	8.6		5.98		20.0
$b = +6$	1172	6	7	54.0	+6	6.4		6.40		15.2
$d = +7$	1216	6	9	9.2	+7	6.2		6.79		9.7
$e = +7$	1312 }	6	22	0.2	+7	13.7 }			7.6*	3.4
	1314 }			3.9		12.1 }				
$f = +8$	1367	6	22	10.1	+8	0.5			8.0	0.0

LIGHT-TABLE.

d	*st.*	*d*	*st.*	*d*	*st.*	*d*	*st.*
− 10.2	6.40	− 3.0	15.50	+ 3.0	18.25	+ 11.0	11.15
10.0	6.40	2.0	18.50	4.0	16.90	12.0	10.80
9.0	6.60	1.0	20.60	5.0	15.85	13.0	9.75
8.0	7.00	− 0.5	21.00	6.0	14.80	14.0	8.50
7.0	7.50	0.0	21.30	7.0	13.70	15.0	7.10
6.0	8.10	+ 0.5	21.00	8.0	12.60	16.0	6.50
5.0	9.25	1.0	20.50	9.0	11.70	+ 16.8	6.40
− 4.0	12.00	+ 2.0	19.30	+ 10.0	11.30		

2509. ζ GEMINORUM.

Max.
R. A. $6^h\ 58^m\ 11^s$ Decl. + 20° 43′.0 (1900).

ELEMENTS OF VARIATION.

1888, Jan. 3.603. 10.15382 E.
Minimum precedes Maximum 5.015*d*.

* The coarse pair designated *e* is too close to be separated by the field-glass, and the light-value and magnitude given are from the united impression of the two stars.

The variability of ζ Geminorum was discovered by Schmidt in 1847. The star was observed by him and by Argelander pretty continuously until 1864. I have observations in 1888 and 1889, and a few in 1892 and 1893, and beyond this, so far as I know, it has been little observed.

It is really a naked-eye star, though the opera-glass is convenient during moonlight. The graphic method is commonly available for the reductions.

The mean light-curve given is that of Argelander (Bonn Observations, Vol. VII, p. 391). It is given as Argelander gives it, beginning at the minimum; the interval from minimum to maximum is slightly greater than that given by Chandler, but for our purposes the difference is not important.

The positions of the comparison-stars are from Yarnall's Catalogue, and the magnitudes the means of those given in the UN, H and DM.

COMPARISON-STARS.

	Positions 1860. R. A. h m s	Decl. ° ′ ″	Mag.	Light (Steps).
δ Geminorum	7 11 46	+ 22 14 11	3.4	9.6
ξ "	6 37 26	+ 13 2 32	3.6	9.3
λ "	7 10 3	+ 16 47 21	3.9	8.1
υ "	7 27 18	+ 27 12 11	4.2	4.9
ν "	6 20 39	+ 20 17 47	4.5	2.0

LIGHT TABLE.

d	*st.*	*d*	*st.*	*d*	*st.*	*d*	*st.*	*d*	*st.*
0.0	2.62	2.5	6.33	5.0	8.22	6.5	7.60	9.0	3.94
0.5	3.08	3.0	6.93	5.13	8.23	7.0	7.08	9.5	3.24
1.0	3.89	3.5	7.41	5.25	8.23	7.5	6.39	10.0	2.72
1.5	4.74	4.0	7.78	5.5	8.19	8.0	5.56		
2.0	5.58	4.5	8.06	6.0	7.96	8.5	4.73		

DORCHESTER, Mass., 1894, Oct. 25.

OBSERVATIONS OF THE TRANSIT OF MERCURY 1894, NOV. 9-10.

E. E. BARNARD.

A more superb day than Saturday, November 10th, could not have happened for the transit of Mercury. Though a slight northerly wind was blowing, it did not materially affect the observations. The air was warm and balmy and was unusually steady for a Mount Hamilton day.

My observations of the transit were confined to the 12-inch,

with which all four contacts were observed, and fifty-three independent measures of the right ascension and declination diameters made. Forty-eight measures of the position of Mercury on the Sun's disc were also obtained.

The unusually good conditions prevailing gave an opportunity to look for evidences of an atmosphere to Mercury and for any unequal shading of his disc.

Neither at contacts nor while on the Sun's disc could any luminous ring be detected. The disc was uniformly dark, round and sharply defined during the intervals of best seeing.

The white spot reported at some previous transits as having been seen on the disc of Mercury, was not visible, and has doubtless been an optical phenomenon unless it was turned away from us at these observations.

It was noticeable that the disc of Mercury was not black—it seemed to be lighter than the sky about the Sun. A micrometer wire placed over the planet was apparently more in contrast than when against the sky outside the Sun's disc. The wire seemed to be about twice as black as Mercury while on the sky there was but little contrast. This illumination of the disc could scarcely have been due to Earth light and I therefore assume that it must have been purely optical.

An attempt was made to see the planet before its entrance onto the Sun, but nothing could be seen of it. Nor was that portion of it visible which was not yet on the Sun, during the interval between first and second contacts.

At the first internal contact the black drop formed but the geometrical contact could be easily decided. This black drop—which was only slight—lasted for about nine seconds after contact.

There was no black drop at the internal contact going off—definition then being excellent.

In the first half of the observations six inches aperture was used, this was reduced to five inches towards the last as the heat became so great as to crack the sun-cap.

An effort was made to see the planet, during mid-transit, with the unaided eye protected by a sun-cap. No trace of it, however, nor of the sun-spots could be seen.

With a small terrestrial telescope,* 1.38 inch in diameter and 5¼ inches focus (which has a magnifying power of 2¼ diameters as near as could be determined) the planet was clearly and unhesitatingly seen. One of the sunspots was also seen with it and ap-

* This is the property of Mr. Burckhalter of the Chabot Observatory, Oakland, California, and was kindly loaned for the above test.

peared about as conspicuous as Mercury. The planet was certainly identified with the finder of the 12-inch so that no hesitation existed as to the certainty of the observation.

I think Mercury could have been seen readily with a slightly less magnifying power.

It is evident, therefore, that though Mercury cannot be seen without a telescope at its transits, it is but little beyond the reach of the unassisted vision, and a magnifying power of from one to two diameters will show it. This holds good for any transit of this planet, as similar observations were made in May, 1891, at which time Mr. Burckhalter saw it through this same glass, though neither he nor I could see it with the eye alone.

Following are my observations of the contacts. They are in Standard Pacific Time which is $8^h\ 0^m\ 0^s$ slow of Greenwich.

The first two were made with the aperture of the 12-inch reduced to 6 inches and a magnifying power of 150 diameters. The last two were made with the five inches aperture and a power of 175:

Contact	I, 1894 Nov.	9th,	19^h	57^m	$9^s.4$*	good, perhaps 2^s late.
"	II, 1894 Nov.	9th,	19	58	42 .7	good.
"	III, 1894 Nov.	10th,	1	11	37 .1	good.
"	IV, 1894 Nov.	10th,	1	13	16 .7	good.

In the final reductions the fractions may be slightly changed. The micrometer measures will be published later.

Mt. Hamilton, 1894, Nov. 11.

PROGRESS OF ASTRONOMICAL PHOTOGRAPHY.

H. C. RUSSELL.†

The telescope used had an objective 8 in. diameter and 12½ ft. focal length. Mr. Hartnup, of course, did the work, and got some very good photographs, of which it is reported, the photographs of the Moon shown at the meeting of the British association at Liverpool were said to have "outstripped all other attempts made elsewhere," and in the report of the Council of the Royal Astronomical Society. February 10th, 1854, it is said that "the beautiful art of photography seems likely to be of much utility in conducing to a more accurate knowledge of the physical condition of celestial bodies."

* The recorded time is that when Mercury was first seen. There was then an extremely small encroachment of its disc estimated as about 2 seconds of time.

† Government Astronomer at Sydney, Australia. Continued from page 105.

At the Royal Astronomical Society meeting, June 9th, 1854, Mr. Hartnup exhibited ten colodion pictures of the Moon, 1.35 in. in diameter and ten enlarged copies, some of which were 4½ in. in diameter. These were all taken during May, 1854.

When thrown upon the screen and made 8 ft. in diameter they were much admired by the astronomers there present, and the president alluded to the gratifying progress of Mr. Hartnup's labors in connection with this interesting subject. The report of the Royal Astronomical Society for 1854, goes on to say that Sir John Herschel strongly recommended,* under date April 24, 1854,† the daily photographic representation of sunspots, and the Kew Committee took the matter up and moved the council of the Royal Society, who decided that the work should be undertaken at Kew, and placed in Mr. De La Rue's hands the duty of carrying out the work for the council. Ross, the optician, made the photoheliograph, which had an objective 3.4 in. diameter, a focus of 50 in., and an enlarging lens which made the Sun's image 12 in. in diameter. While this was going on an amateur, the Rev. J. B. Reade, M. A., F. R. A. S., whom I have already quoted, was very busy trying to take photographs with what must have been in those days a very large instrument. The Craigh telescope, at Wandsworth, which he used, had a diameter of 2 ft. and a focal length of 77 ft. It is not stated whether it was a refractor, but "the true photogenic focus was difficult to find," and he goes on to say, "that so large an object glass worked by hand should do so much with the stars is far from discreditable."‡ He then speaks of reworking the surfaces of the object glass, which seems to leave no doubt that it was not a reflector, which has one surface only. With such a long focus the Moon's image should be nearly 8 in. in diameter; the time of exposure for a collodion picture of the Moon was thirty-five seconds. This telescope was not equatorially mounted, and the Moon's apparent motion when near the meridian was counteracted by a "screw motion given to the eye end of the telescope;" the rate was guided by looking through the collodion at a crater kept on cross wires; from a negative taken on September 6th, 1854, a negative 9 in. in diameter was made, which was compared with one taken by Bond at Harvard Observatory, and Mr. Reade adds, "in this photograph all the more important features of the Moon's surface will be discovered by those who are familiar with their telescopic appearance." I

* Royal Astronomical Society, Monthly Notices, vol. XV., p. 132.
† This was the second time, see Cape Observations, p. 435, foot note.
‡ British Association Report, 1854, p. 10.

have already quoted his comparison of his photograph with the Bond photograph.

In 1857 Professor Henry Draper,* after seeing Lord Rosse's great reflector, returned to America with his mind made up to construct a large reflector and use it for astronomical photography. He made a metallic reflector 15½ in. diameter and 12 ft. focus, but soon discarded it for a silvered glass one of same size and 12 ft. 6 in. focus.† He made 1,500 photographs of the Moon with it, of which the best was made September 3d, 1863, and was enlarged to 3 ft., the original being $1\frac{4}{10}$ in. diameter. In 1857 Bond,‡ having supplied the driving clock of the equatorial with the spring governor which he had invented, again turned his attention to photography, and by the aid of the more rapid collodion plates took photographs of stars of various magnitudes up to the sixth; the brighter star of Zeta Ursæ Majoris recorded itself in two seconds and the companion in eight seconds. Measures were made of these, and in this early stage it was found that the probable error of a single measure of the distance between them was only $\pm 0''.12$. Star pictures were made soon afterwards by Mr. De La Rue and Mr. Rutherford. At the meeting of the Royal Astronomical Society on November 13th, 1857, Mr. Airy, the Astronomer Royal, exhibited Bond's photographs of this double star, Zeta Ursæ Majoris, and used these memorable words—"This photograph marks a step of very great importance which has been made, of which either as regards the self-delineation of clusters of stars, nebulæ, and planets, or as regards the self-delineation of observations, it is impossible at present to estimate the value." Mr. Bond had, in 1857, obtained photographs of the bright stars Castor and Vega, and now with more sensitive collodion he was able to take the companion of Zeta Ursæ Majoris, which is fifth magnitude and emerald green in color, so would photograph in normal conditions. The time required was eight seconds. Now the Brothers Henry photograph such a star with a 13 in. star camera in one-fifth of a second. Bond's objective reduced to 13 in. would take $10^s.7$ to photograph this star, and therefore fifty-three and a half times longer than it does now.

Hartnup, in Liverpool, 1864, took 124 times longer for the Moon than it does in Sidney to-day.

* Quarterly Journal of Science, 1864, pp. 381 and 384.

† Quarterly Journal of Science, 1864, p. 382.

‡ An Investigation into Stellar Photography by Professor Pickering; see also Astron. Nachrichten, 1105; also Astronomical Register, Vol. I, p. 65, which says the Moon photos. were 3-in. in diameter.

Mr. De La Rue's* work in 1852 has already been mentioned, and the photographs then taken without clock movements were so promising that he determined to have a proper clock. This was not finished till 1857, and he then devoted his whole energy and his observatory to the study and practice of astronomical photography, and everyone is aware of his pre-eminent success—success eclipsing all that had been done before; and even in the present day his work must still be classed as good, but not equal to the best modern efforts.

At the British Association, in September, 1859, he exhibted two original negatives of the Moon, which would bear considerable magnifying power—two enlargements from these 8 in. in diameter, other enlargements 3½ in. diameter; photographs of Jupiter, showing his belts and satellites; and one of the Moon, with Saturn near the limb, taken in fifteen seconds.

From the same source I learn that experiments in lunar photography were made by Lord Rosse with the 6 ft. reflector. Having no clock motion for the telescope, he applied to it a sliding plate holder of the kind used by De La Rue in his first experiments, but this is said not to have met all the exigencies of the case. The telescope was wanted for other purposes, and from the fact that no photographs with the great reflector were published, it is probable they were not so good as it was hoped they would be. In his best photographs of the Moon† De La Rue claimed to have recorded in a picture of the Moon $1\frac{1}{10}$ in. diameter details so small that any subsequent change over a space measuring two miles each way must be detected, and claimed‡ to be able, with best weather and chemicals, to get a photograph of dark parts of crescent Moon in from twenty to thirty seconds which would show all the parts visible near the dark limb.

Having made a new driving clock in 1857, Bond devoted the great refractor at Harvard College to a series of experiments, which lasted to 1858,§ making photographs of stars with various apertures from the full 15 in. down to 1 in., to ascertain the possibility of classifying the stars by their photographic images on the plate, which, being suitable for accurate measurement, he deemed more satisfactory than the method of eye estimates in common use; and he came to the conclusion that the photographic magnitudes of stars increase by equal areas for equal increases in time

* British Association Report, 1859, pp. 130, 139, 140.
† Royal Astronomical Society Monthly Notices, Vol. XIX., p. 354.
‡ Royal Astronomical Society Monthly Notices, Vol. XIX., p. 356
§ British Association Report, 1859, pp. 139, 140; also Astron. Nachricten, 1105, 1129, and 1158; also Monthly Notices, Vol. XIX., pp. 138 and 139.

of exposure, so proving that the photographic method of determining star magnitudes proceeded on the same principle as eye estimates, and anticipating by twenty-six years the same work which has been gone over by several astronomers for the star charting now in progress.* Professor Pritchard, however, came to another conclusion, viz., that the area of the star image varies as the square root of the time of exposure.

The photo-heliograph,† which had been set up at Kew on the earnest recommendation of Sir John Herschel, already referred to, was completed at the end of February, and work on the Sun was begun with it on March 1st, 1858, but at first was not continuous owing to the necessity for modifications in order to make the exposure short enough. This was ultimately accomplished by a shutter with a slit in it working in the focus of the objective.

About 1860 Mr. De La Rue‡ turned his attention to the possibility of photographing the details of sunspots with his reflector, and exhibited some on a scale of 3 ft. to the Sun's diameter. They were not so good as he hoped to make them, but the cause he thought was in the secondary magnifier. They were taken in one-twentieth of a second. It does not appear that they ever came to perfection; indeed it is well known now that the chief difficulty is vibration in the atmosphere, which is seldom absent; but he pursued the subject, and we are told in 1863§ that he had exhibited some photographs of sunspots on the enormous scale of 13 ft. for the Sun's diameter, and also some prints from them produced by Herr Pretsche's process (untouched by the graver).

Meantime this enthusiast, whose ability and energy for many years led the way in the application of photography to astronomy, was busy photographing star clusters with his reflector, but he found it better to use a large portrait lens, which gave very encouraging results. He remarks "the difficulty does not consist in fixing the images of the stars, but in finding the images when they are imprinted, for they are no bigger than the specks common to the best collodion."

At this time‖ some curiosity existed as to the possibility of photographing comets. "I tried," writes De La Rue, "with my reflector, on the appearance of Donati's comet in 1858, several times, without success, and on the appearance of the comet of the

* Proceedings of Royal Society, 1886, No. 247, p. 207.

† British Association Report, 1859, p. 149.

‡ British Association Report, 1861, p. 96; also Royal Astronomical Society Monthly Notices, p. 278, with plate.

§ Astronomical Register, Vol. I, p. 118, 119.

‖ British Association Report, 1861, p. 95; also Royal Astronomical Society Monthly Notices, Vol. XIX., p. 138.

present year (1861) I tried not only with my telescope, but also with a portrait lens, and with an exposure of fifteen minutes, not seconds, but I failed to get the slightest trace with either." The care in stating the time of exposure was probably due to a report that Mr. Usherwood,* of Walton Common, in Surrey, had secured a photograph of Donati's comet on September 26th, 1858. He used an ordinary portrait lens without equatorial stand, but set the camera in the ordinary way, and exposed for seven seconds. The picture was about an inch long, and bore enlargement to some extent. Mr. Usherwood used a portrait lens of very short focus on a hill 700 ft. high. Still the great difference between his exposure and those of Mr. De La Rue is not easily accounted for, although many accepted Mr. Usherwood's picture as the first one ever made of a comet.

We are told† that in his photographs of the Moon and other objects Mr. De La Rue used a negative collodion containing iodide of cadmium and avoided acetic acid and alcohol in the bath, which he made as neutral as possible. In this way he obtained photographs of full Moon, either instantaneously or in five or six seconds, and in its half phase in twenty to thirty seconds.‡ Early§ in 1859 Mr. De La Rue had the courage to propose, and the ability finally to carry out, the transfer of the Kew photo-heliograph to Spain in 1860, in order to photograph the total eclipse of July 18th in that year. It was a bold experiment, and was crowned with success. In estimating the conditions we must remember that he had no chance of finding out beforehand the time of exposure for red prominences. Two photographs of the totality were secured; each had an exposure of one minute, and each showed the red prominences clearly, and served for ever to set at rest the much vexed question of those days, viz., whether they belonged to the Sun or the Moon, for the photographs proved definitely that the red prominences belonged to the Sun. Mr. De La Rue's station was at Rivabellosa, in Spain, and on the Mediterranean coast of Spain, 240 miles from Rivabellosa, Father Secchi‖ had set up his Observatory and took photographs with a 9-in. refractor on a smaller scale than those taken by Mr. De La Rue, but they fully confirmed the results obtained by the English party—that the prominences belonged to the Sun.

In the first photograph taken at Rivabellosa there was to be

* Royal Astronomical Society Monthly Notices, Vol. XIX., p. 138.
† Astronomical Register, Vol. I, pp. 67 and 118.
‡ British Association Report, 1859, p. 137.
§ Phil. Trans., 1862, p. 333.
‖ Astronomical Register, Vol. I, p. 119.

seen to the east of the Sun a totally detached prominence or cloud of curved or boomerang form, and in the second this was partly covered by the advancing limb of the Moon, and a fresh lot showed themselves on the other side. The light of the red prominences was estimated to be photographically 180 times brighter than that of the Moon.*

On 27th of February, 1863,† and on 3rd of March of the same year Dr. Huggins led the way in photographing star spectra, and found that when the spectrum of Sirius was caused to fall upon a sensitive collodion surface an intense photographic spectrum of the more refrangible part was obtained; but, "from want of accurate adjustment of the focus, or from the motion of the star not being exactly compensated by the clock movement, or from atmospheric tremors, the spectrum, though tolerably well defined at the edges presented no indication of lines."

OCCULTATION OF THE PLEIADES, DEC. 10-11, 1894.

H. C. WILSON.

It is seldom that the observer has the opportunity to witness more than one or two occultations of bright stars in one night. On the night of December 10, however, those in the United States may see seven of the eight bright stars in the Pleiades group in turn disappears behind the advancing disc of the Moon, reappearing again after occultations lasting from a few minutes to an hour. The Washington mean times of immersion and emersion of each star, as seen from Washington, were given in our tables last month. These, however, will not serve for other localities, because the parallax of the Moon as seen from other places will be quite different.

In order to give the reader some idea of the displacement of the Moon due to parallax, and to show an easy method of getting the approximate times of the occultations at any place, we have prepared the accompanying diagram. The black discs lettered *b*, *c*, *d*, *e*, η, *f*, *g* and *h* represent the eight bright stars of the Pleiades, and the black dots represent fainter stars of the group, some of which will be visible in the presence of the Moon.

The line *AB* shows the course of the centre of the Moon unaffected by parallax, *i. e.*, as seen from the Earth, from 10^h P. M.

* Phil. Trans., 1862, p. 405.
† Phil. Trans., 1864, p. 428.

PLATE XV.

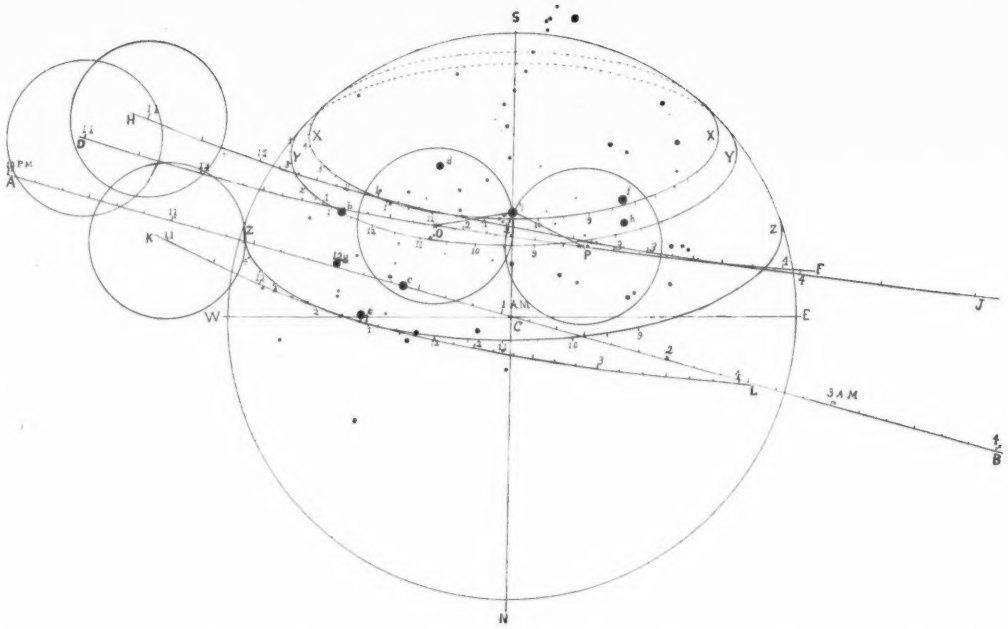


Diagram Showing the Apparent Course of the Moon through the Pleiades Group on the Night of Dec. 10-11, 1894.

AB represents the path of the Moon's center as seen from the center of the Earth, DF as seen from Washington, HJ from Northfield and KL from the City of Mexico. Scale: 1mm = 74″.5.

to 4^h A. M. The line *DF* indicates the apparent course of the Moon's centre as seen from Washington, *HJ* as seen from Northfield and *KL* as seen from the city of Mexico. The three circles at the left represent the Moon as seen from the three places at 11^h P. M., Central Standard time. Its place as seen from the centre of the Earth at the same moment would be at 11 on the line *AB*. The corresponding positions of the Moon's centre at subsequent hours are indicated by the numbers 12, 1, 2, 3 and 4 on each line. The hour spaces have been subdivided into 10-minute spaces, so that the reader may easily determine the time when the centre of the Moon will be at any given point on either line within one minute, by estimating the fraction of a space from the nearest 10 minute mark to the given point.

A simple method of finding the time of the occultation of any star at one of the three mentioned places will be the following: cut out of white paper a disc of the same size as the smaller circles in the diagram and cut a small round hole through its centre. Place the disc on one of the lines (DF for Washington) and move it slowly toward the right, keeping the center of the disc exactly on the line. You will thus represent the apparent size and motion of the Moon among the stars. When the advancing edge of the disc is exactly over the center of one of the star images, η (Alcyone) for instance, mark on the line the place of the center of the round hole. This is found to be at *O* for Washington and we estimate that it is one tenth of a space, or one minute, back from the $1^h\ 50^m$ mark, which gives the time of the beginning of occultation or immersion of η as $1^h\ 49^m$ A. M. Central time. In the same way, when the retreating edge of the disc is exactly over η the center of the disc is at *P*, which gives the time of *emersion*, or end of occultation, as $2^h\ 48^m$ A. M., Central time.

As a perfect circle of the required size is somewhat difficult to cut out, a better method is to use a pair of dividers, spreading the points so that they will measure the radius of the Moon, ηO or ηP. Place one point of the dividers at the center of the star image and with the other describe short areas of a circle intersecting the path of the Moon's center. The intersection at the left will mark the moment of immersion, that at the right the emersion of the star.

Applying either of these methods we get the following results for the three places mentioned:

Star	Washington. Immersion	Washington. Emersion	Northfield. Immersion	Northfield. Emersion	Mexico. Immersion	Mexico. Emersion
b Electra	12 32 A. M.	1 43 A. M.	12 10 A. M.	1 21 A. M.	———	———
g Celoena	12 47 "	1 35 "	12 40 "	1 00 "	12 02 A. M.	1 12 A. M.
e Taygeta	———	———	———	———	12 17 "	1 40 "
c Maia	1 23 "	1 57 "	1 25 "	1 25 "	12 44 "	1 51 "
d Merope	1 26 "	2 07 "	12 54 "	1 53 "	———	———
η Alcyone	1 49 "	2 48 "	1 28 "	2 35 "	———	———
f Atlas	2 39 "	3 23 "	2 21 "	3 12 "	———	———
h Pleione	2 35 "	3 30 "	2 18 "	3 18 "	———	———

These are all Central Standard times. As observers at Washington will use Eastern time, they should add 1 hour to the times given. Those in Mexico will probably use Mountain time and should therefore subtract 1 hour, or, if they use the local time of the Observatory at Chapultepec, subtract 36.6 minutes.

A glance at the diagram will show that at Washington and Northfield the Moon will pass to the south of the star *e*, and that at Northfield the star *c* may also escape occultation, it being very close to the north edge of the Moon's disc at $1^h\ 25^m$ A. M. At Mexico, on the other hand, these two with *g* will be the only ones of the brighter stars occulted.

In order to observe the emersion of a star the observer must know, not only when the emersion is to occur, but also at what point on the edge of the disc the star is to reappear. This latter is usually designated by the position angle from the north point, counted around in the direction *N E S W*, *N* being represented by 0°, *E* by 90°, *S* by 180° and *W* by 270°. The position angle may be easily obtained by means of the paper disc referred to above. The latter should have radial lines drawn to its circumference, 10° apart, and every third one numbered 0°, 30°, 60°, etc., to 330°. Then when the disc is placed on the diagram as described above, if the 0° — 180° diameter is kept parallel to the line *N S* the position angle of each star at immersion or emersion may be read off directly.

Now I suppose that the reader, who does not live near Northfield or Washington or Mexico, will wish to know how to get the times for his or her own locality. The best way is to draw upon the chart the apparent path of the Moon's center for your own place, and then the times can be taken off the chart by the methods already given. How to do this I can best explain by giving the method employed in constructing the chart for Northfield.

The data obtained from the Nautical Almanac for the star Alcyone (η), which we may take as the center of the Pleiades group, are as follows:

		h	m	
Time of conjunction in R. A.	= Dec. 10	13	55.3	Washington mean time.
	= Dec. 10	19	03.5	Greenwich mean time.
	= Dec. 11	1	03.5	A. M. Central standard time.
Apparent R. A. of Moon and star	$= 3^h\ 41^m\ 15^s.5$			
Apparent Decl. of star	$= +23°\ 47'\ 00''$			
Apparent Decl. of Moon	$= +24\ \ 08\ \ 27$			
Moon's hourly motion in R. A.	$= +150^s.8$			
Moon's hourly motion in Decl.	$= +572''$			
Moon's equatorial horizontal parallax	$= 59'\ 14'' = 3554''$			
Moon's apparent semi-diameter	$= 16'\ 10'' = \ 970''$			
Moon's meridian passage at Greenwich	$= 10^h\ 00^m.5$ Greenwich mean time.			
Hourly change of meridian passage	$= 2^m.39.$			

The longitude of Northfield is $6^h\ 12^m\ 36^s$ west from Greenwich and the latitude north 44° 27′ 42″. For our present purpose we use the geocentric latitude, which is 11′ 30″ less than the true latitude, or 44° 16′ 12″. The reduction from apparent to geocentric latitude is about 11′ for the middle latitudes of the United States and 10′ for the southern boundary.

With a radius equal to the Moon's equatorial horizontal parallax, 3554″, draw the circle *NESW* and the diameters *NS* and *EW*. At *C* lay off to the left the Moon's hourly motion multiplied by 15 times the cosine of the Moon's declination ($150^s.8 \times 15 \times \cos 24°\ 08'.4 = 2064''$); at the point thus marked off erect a perpendicular equal to the Moon's hourly motion in declination 572″. Connect the extremity of the perpendicular with *C*. The diagonal thus drawn represents the Moon's hourly motion along its path. Extend it to *A* and *B* and with a pair of dividers mark off the Moon's position at successive hours. As the time of conjunction is $1^h\ 03^m.5$ A. M., Central time, we mark the 1^h point at the left of *C* at a distance equal to 3.5/60 of the hourly motion.

The motion is not exactly uniform, and the line *AB* should be slightly concave upward instead of straight, but for the present purpose it is hardly worth while to take account of the curvature. The little crosses to the right of the hour marks indicate the amount of the corrections for curvature.

To construct the parallactic ellipse *XX* for Northfield, take the sum and difference of the geocentric latitude of the place and the declination of the Moon, 44° 16′.2 + 24° 08′.4 = 68° 24′.6 and 44° 16′.2 − 24° 08′.4 = 20° 07′.8. Multiply the sines of these two angles by 3554″ and measure the resulting distances from *C* toward *S*. This will give the extremities of the minor axis and the middle point between them will be the center of the ellipse. From this center lay off to the right and left the distance

3554″ multiplied by the cosine of the latitude 44° 16′.2 = 2545″, which will give the vertices *X*. The ellipse may then be drawn through the four points by means of an ellipsograph, or other points may be constructed in the following manner:

Multiply the semimajor axis 2545″ by the sines of the angles 15°, 30°, 45°, 60° and 75°, and lay off the resulting distances each way from the center along the line *XX*. At the points thus determined erect perpendiculars, extending them above and below the line to distances equal to the semiminor axis multiplied by the cosines of the corresponding angles, 15°, 30°, 45°, 60° and 75°. The extremities of these perpendiculars will all be points on the ellipse, which may then be drawn off-hand. Moreover the points will be 15° or 1^h apart and will represent the place of the Moon's center as displaced from *C* by parallax at intervals of an hour.

From the date given we find that the Moon will be on the meridian at Greenwich at 10^h 00^m.5 P. M., and that the hourly change is 2^m.39. As the longitude of Northfield is 6^h 12^m 36^s = 6^h.21 the hourly change between the two places will amount to 6.21 × 2.39 = 14^m.8, and the time of meridian passage at the latter place will be 10^h 00^m.5 + 14^m.8 = 10^h 15^m.3. This is local time and must be still further corrected by adding 12^m.6 to reduce it to Central Standard time. As the parallax is wholly in declination at the time of meridian passage, the point on the ellipse directly over *C* should be marked 10^h 27^m.9 and the 10 hour point is near the middle of the first space to the right, the 11 hour point in the space to the left and so on. A little careful work with the dividers and a fine scale will enable the reader to locate the hour and half hour points within about a minute. Of course he will not neglect to use his own latitude and longitude and to re-calculate all the numbers which depend upon these.

The next thing is to construct the apparent path of the Moon, which is the resultant of the two motions, along *AB* and around the parallactic ellipse. From *C* draw a line to 11 on the ellipse. From 11 on the line *AB* draw an equal and parallel line. This will give the point 11 on the line *HJ*. In the same way draw lines from 12, 1, 2, etc., on *AB*, equal and parallel to lines from *C* to the corresponding points on the ellipse. Through their extremities draw the smooth curve *HJ*, which will represent the Moon's apparent path as affected by parallax. The intermediate points may be located by division of the spaces with the dividers, care being taken to make the smaller spaces diminish or increase in length as the larger ones do.

The positions of the stars were located as follows: As the chart

was constructed for the moment of conjunction of η and the Moon, that star should be directly above C at a distance equal to the difference between its declination and that of the Moon, or 1287″. The position angles and distances of the other bright stars from η, as given in the following table, were plotted with a protractor and scale. Then the smaller stars were located by projecting on the chart one of the photographs of the Pleiades taken at Goodsell Observatory.

Star.	Position Angle.	Distance.
	° ′	″
b Electra	270 13	2143
c Maia	340 13	1657
d Merope	238 46	1107
e Taygeta	304 21	2277
η Alcyone	—	—
f Atlas	97 07	1391
g Celœna	286 12	2299
h Pleione	84 46	1403

The method I have used is only an approximate one, but it gives at once some idea of the relative positions of the Moon and the group of stars and the magnitude of the displacement due to parallax. When once the method is understood, the chart can be constructed in a couple of hours. The times of immersion and emersion of the principal stars may be read off in a few minutes. The accuracy to be attained may be seen by comparing the following numbers, which are the results of accurate computations, with those in the early part of this article:

COMPUTED TIMES OF OCCULTATION.

	Northfield.		Washington.	
	Immersion	Emersion	Immersion	Emersion
	h m	h m	h m	h m
b Electra	12 10 A. M.	1 20 A. M.	12 33 A. M.	1 43 A. M.
c Maia	———	———	———	———
d Merope	12 52 "	1 52 "	1 23 "	2 07 "
η Alcyone	1 26 "	2 34 "	1 50 "	2 49 "
f Atlas	2 22 "	3 10 "	2 40 "	3 21 "
g Celœna	12 40 "	12 58 "	12 45 "	1 35 "
h Pleione	2 17 "	3 18 "	2 36 "	3 29 "

PLANET NOTES FOR JANUARY.

H. C. WILSON.

Mercury will be at superior conjunction, that is, on the farther side of the Sun, Jan. 9 and so will not be visible during this month.

Venus will be evening planet, setting too soon after the Sun to be in good position for observation. Venus will be in conjunction with the one-day-old Moon, 1° 21′ north of the latter, at 9 o'clock on the evening of Jan. 26.

Earth will be at perihelion Jan. 2 at 6^h P. M.

Mars will be in conjunction with the Moon, about 2° south of the latter, at 2^h P. M. Jan. 5. By this time all our readers will have become so familiar with the aspect of the ruddy planet in Pisces that we have no need to point out its location. During January it will be west of the meridian in the evening and will set shortly after midnight. Up to Nov. 23 the south polar snow-cap had not reappeared.

Jupiter is in Gemini and his brilliancy on some of these clear sparkling nights is sufficient to cast respectable shadows of large objects upon the white background of the snow. He is in his best position for observation during this opposition. The belts show plainly in a very small telescope and the details shown on the planet's surface by a large telescope on a good night will defy the power of an artist to depict them. The four bright satellites may always be seen, except when they are behind or in the shadow of the planet and when in transit across the disc. Under some circumstances they may also be seen in transit and their shadows, cast as black round dots upon the planet, are quite conspicuous when the seeing is good. We warn the reader, however, not to attempt to see the new (fifth) satellite, discovered by Barnard, for it can only be seen with the aid of a very powerful telescope. The smallest telescope with which it has been seen, so far as we are aware, is the 18-inch of Dearborn Observatory, Evanston, Ill.

Saturn and *Uranus* are hardly yet in good position for the amateur. They may be observed in the morning. Saturn will be at quadrature, 90° west from the Sun, Jan. 26. He will be in conjunction with the Moon, about 6° north of the latter, Jan. 18 at 1 P. M. Uranus will be in conjunction with the Moon, about 5° north of it, on the 19th at 11^h 35^m A. M. Saturn is in Virgo near the west boundary of Libra, moving slowly eastward. Uranus is in Libra a little southeast of the star ν.

Neptune is in Taurus a little south and west from the star ι and moving slowly westward.

Planet Tables for January.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

Date.	R. A.	Decl.	Rises.	Transits.	Sets.
	h m	° ′	h m	h m	h m
			MERCURY.		
Jan. 5.....	19 2.1	− 24 27	7 37.1 A. M.	11 55.0 A. M.	4 12.6 P. M.
15.....	20 6.3	− 22 24	7 58.0 "	12 26.8 "	4 54.8 "
25.....	21 16.8	− 19 39	8 7.0 "	12 57.7 "	5 47.4 "
			VENUS.		
Jan. 5.....	19 43.9	− 22 26	8 15.6 A. M.	12 43.6 P. M.	5 11.6 P. M.
15.....	20 36.9	− 19 58	8 16.8 "	12 57.4 "	5 30.4 "
25.....	21 27.6	− 16 32	8 12.7 "	1 8.7 "	5 57.5 "
			MARS.		
Jan. 5.....	1 59.0	+ 13 20	12 0.0 M.	6 57.3 P. M.	1 54.6 A. M.
15.....	2 15.8	+ 14 56	11 30.5 A. M.	6 34.7 "	1 38.9 "
25.....	2 34.5	+ 16 34	11 01.7 "	6 12.9 "	1 24.1 "
			JUPITER.		
Jan. 5.....	5 57.4	+ 23 16	3 11.5 P. M.	10 55.3 P. M.	6 39.1 A. M.
15.....	5 52.3	+ 23 16	2 27.1 "	10 10.9 "	5 54.7 "
25.....	5 48.2	+ 23 17	1 43.8 "	9 27.6 "	5 11.4 "
			SATURN.		
Jan. 5.....	14 17.4	− 11 14	1 56.5 A. M.	7 15.0 A. M.	12 33.5 P. M.
15.....	14 19.8	− 11 23	1 19.8 "	6 37.9 "	11 56.0 "
25.....	14 21.5	− 11 29	12 42.9 "	6 0.3 "	11 18.7 "

URANUS.

Date. 1894.	R. A. h m	Decl. °	Rises. h m	Transits. h m	Sets. h m.
Jan. 5	15 6.1	− 17 7	3 9.8 A. M.	8 3.2 A. M.	12 56.6 P. M.
15	15 7.7	− 17 12	2 32.8 "	7 25.8 "	12 18.8 "
25	15 8.7	− 17 18	1 54.0 "	6 47.3 "	11 39.8 A. M.

NEPTUNE.

Jan. 5	4 34.9	+ 20 56	2 15.9 P. M.	9 47.7 P. M.	5 11.9 A. M.
15	4 40.7	+ 20 55	1 35.6 "	9 7.4 "	4 39.2 "
25	4 57.0	+ 20 54	12 55.6 "	8 27.4 "	3 59.2 "

THE SUN.

Jan. 5	19 6.0	− 22 35	7 36.7 A. M.	12 5.7 P. M.	4 34.7 P. M.
15	19 49.5	− 21 04	7 34.3 "	12 9.7 "	4 45.1 "
25	20 31.6	− 18 53	7 28.2 "	12 12.6 "	4 56.9 "

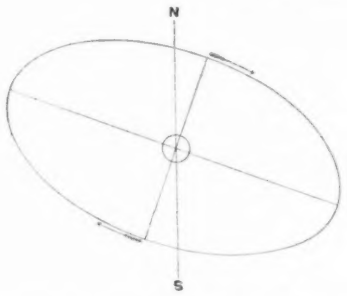
Occultations Visible at Washington.

Date 1895	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	IMMERSION Angle from N p't. °	EMERSION Washington M. T. h m	EMERSION Angle from N p't. °	Duration. h m
Jan. 1	φ Aquarii	4.1	8 13	61	9 20	229	1 07
1	96 Aquarii	5.6	11 29	31	12 13	276	0 44
4	100 Piscium	6.8	13 38	27	14 17	293	0 39
11	γ Cancri	4.3	13 31	177	14 09	337	0 38
14	80 Cancri	6.8	9 01	128	9 54	284	0 53
18	B.A.C. 4923	7.3	14 37	93	15 31	326	0 54
19	B.A.C. 5197	6.0	12 54	66	13 31	339	0 37
27	42 Aquarii	5.8	7 04	9	7 43	288	0 39

Phases and Aspects of the Moon.

	Central Time. d	h	m
First Quarter	Jan. 4	1	52 A. M.
Full Moon	11	12	50 A. M.
Perigee	11	6	10 P. M.
Last Quarter	17	4	55 P. M.
New Moon	25	3	26 P. M.
Apogee	26	11	10 A. M.

The Satellite of Neptune.



APPARENT ORBIT OF THE SATELLITE OF NEPTUNE, AS SEEN IN AN INVERTING TELESCOPE.

CENTRAL TIMES OF GREATEST ELONGATIONS.

Period $5^d\ 21^h.045$.

Northeast.		Northwest.	
Dec. 29	5.9 P. M.	Jan. 1	4.5 P. M.
Jan. 4	3.0 "	7	1.6 "
10	12.2 "	13	10.7 A. M.
16	9.2 A. M.	19	7.8 "
22	6.3 "	25	4.9 "
28	3.4 "	31	2.0 "

In the diagram the central circle represents the planet and is drawn to the same scale as the orbit of the satellite.

Phenomena of Jupiter's Satellites.

Central Time.

	h	m				h	m		
Jan.	1	11	38 P. M.	I	*Oc. Dis.	Jan. 11	7	23 P. M.	I	*Tr. Eg.
	2	2	9 A. M.	I	*Ec. Re.		7	54 "	I	*Sh. Eg.
		2	4 P. M.	II	Tr. In.	12	2	15 "	I	Oc. Dis.
		2	36 "	II	Sh. In.		5	1 "	I	*Ec. Re.
		4	41 "	II	Tr. Eg.	13	5	28 A. M.	II	Tr. In.
		5	14 "	II	*Sh. Eg.		6	31 "	II	Sh. In.
		8	57 "	I	*Tr. In.		8	4 "	II	Tr. Eg.
		9	14 "	I	*Sh. In.		9	10 "	II	Sh. Eg.
		11	13 "	I	*Tr. Eg.		11	33 "	I	Tr. In.
		11	30 "	I	*Sh. Eg.		12	6 P. M.	I	Sh. In.
	3	6	5 "	I	*Oc. Dis.		1	49 "	I	Tr. Eg.
		7	56 "	III	*Tr. In.		2	22 "	I	Sh. Eg.
		8	37 "	I	*Ec. Re.	14	8	42 A. M.	I	Oc. Dis.
		9	10 "	III	*Sh. In.		11	30 "	I	Ec. Re.
		10	45 "	III	*Tr. Eg.		12	42 P. M.	III	Oc. Dis.
	4	12	2 A. M.	III	*Sh. Eg.		5	47 "	III	*Ec. Re.
		9	0 "	II	Oc. Dis.	15	12	22 A. M.	II	*Oc. Dis.
		12	13 P. M.	II	Ec. Re.		4	6 "	II	Ec. Re.
		3	23 "	I	Tr. In.		6	0 "	I	Tr. In.
		3	43 "	I	Sh. In.		6	34 "	I	Sh. In.
		5	39 "	I	*Tr. Eg.		8	16 "	I	Tr. Eg.
		5	59 "	I	*Sh. Eg.		8	51 "	I	Sh. Eg.
	5	12	31 "	I	Oc. Dis.	16	3	8 "	I	*Oc. Dis.
		3	6 "	I	Ec. Re.		5	58 "	I	Ec. Re.
	6	3	12 A. M.	II	*Tr. In.		6	37 P. M.	II	*Tr. In.
		3	54 "	II	*Sh. In.		7	50 "	II	*Sh. In.
		5	48 "	II	Tr. Eg.		9	14 "	II	*Tr. Eg.
		6	32 "	II	Sh. Eg.		10	29 "	II	*Sh. Eg.
		9	49 "	I	Tr. In.	17	12	26 A. M.	I	*Tr. In.
		10	11 "	I	Sh. In.		1	3 "	I	*Sh. In.
		12	5 P. M.	I	Tr. Eg.		2	42 "	I	*Tr. Eg.
		12	28 P. M.	I	Sh. Eg.		3	20 "	I	*Sh. Eg.
	7	6	57 A. M.	I	Oc. Dis.		7	35 "	IV	Ec. Dis.
		9	23 "	III	Oc. Dis.		8	7 "	IV	Ec. Re.
		9	34 "	I	Ec. Re.		9	35 P. M.	I	*Oc. Dis.
		1	46 P. M.	III	Ec. Re.	18	12	27 A. M.	I	*Ec. Re.
		10	7 "	II	*Oc. Dis.		2	34 "	III	*Tr. In.
	8	1	30 A. M.	II	*Ec. Re.		5	9 "	III	Sh. In.
		4	15 "	I	*Tr. In.		5	24 "	III	Tr. Eg.
		4	40 "	I	*Sh. In.		8	4 "	III	Sh. Eg.
		6	31 "	I	Tr. Eg.		1	30 P. M.	II	Oc. Dis.
		6	56 "	I	Sh. Eg.		5	23 "	II	*Ec. Re.
	9	12	3 "	I	*Oc. Dis.		6	52 "	I	*Tr. In.
		4	3 "	I	*Ec. Re.		7	32 "	I	*Sh. In.
		4	20 "	II	Tr. In.		9	9 "	I	*Tr. Eg.
		5	13 P. M.	II	*Sh. In.		9	48 "	I	*Sh. Eg.
		6	56 "	II	*Tr. Eg.	19	4	1 "	I	Oc. Dis.
		7	51 "	II	*Sh. Eg.		6	56 "	I	*Ec. Re.
		10	41 "	I	*Tr. In.	20	7	47 A. M.	II	Tr. In.
		11	8 "	I	*Sh. In.		9	9 "	II	Sh. In.
	10	12	57 A. M.	I	*Tr. Eg.		10	24 "	II	Tr. Eg.
		1	25 "	I	*Sh. Eg.		11	48 "	II	Sh. Eg.
		7	49 P. M.	I	*Oc. Dis.		1	19 P. M.	I	Tr. In.
		10	32 "	I	*Ec. Re.		2	1 "	I	Sh. In.
		11	14 "	III	*Tr. In.		3	35 "	I	Tr. Eg.
	11	1	9 A. M.	III	*Sh. In.		4	17 "	I	Sh. Eg.
		2	3 "	III	*Tr. Eg.	21	10	28 A. M.	I	Oc. Dis.
		4	3 "	III	*Sh. Eg.		1	25 P. M.	I	Ec. Re.
		11	14 "	II	Oc. Dis.		4	5 "	III	Oc. Dis.
		2	48 P. M.	II	Ec. Re.		6	54 "	III	*Oc. Re.
		5	7 "	I	*Tr. In.		7	2 "	III	*Ec. Dis.
		5	37 "	I	*Sh. In.		9	48 "	III	*Ec. Re.

	h	m			
Jan. 22	2	39	A. M.	II	*Oc. Dis.
	6	41	"	II	Ec. Re.
	7	45	"	I	Tr. In.
	8	29	"	I	Sh. In.
	10	1	"	I	Tr. Eg.
	10	46	"	I	Sh. Eg.
23	4	54	"	I	Oc. Dis.
	7	54	"	I	Ec. Re.
	8	57	P. M.	II	*Tr. In.
	10	28	"	II	*Sh. In.
	11	34	"	II	*Tr. Eg.
24	1	7	A. M.	II	*Sh. Eg.
	2	11	"	I	*Tr. In.
	2	58	"	I	*Sh. In.
	4	28	"	I	Tr. Eg.
	5	15	"	I	Sh. Eg.
	11	21	"	I	*Oc. Dis.
25	2	23	"	I	*Ec. Re.
	5	58	"	III	Tr. In.
	8	47	"	III	Tr. Eg.
	9	9	"	III	Sh. In.
	12	4	P. M.	III	Sh. Eg.
	3	48	"	II	Oc. Dis.
	4	39	"	IV	Sh. In.
	5	46	"	IV	*Sh. Eg.
	7	58	"	II	*Ec. Re.
	8	38	"	I	*Tr. In.
	9	26	"	I	*Sh. In.
	10	52	"	I	*Tr. Eg.
	11	43	"	I	*Sh. Eg.
26	5	48	"	I	*Oc. Dis.
	8	51	"	I	*Ec. Re.

	h	m			
Jan. 27	10	8	A. M.	II	Tr. In.
	11	46	"	II	Sh. In.
	12	45	P. M.	II	Tr. Eg.
	2	26	"	II	Sh. Eg.
	3	5	"	I	Tr. In.
	3	55	"	I	Sh. In.
	5	21	"	I	*Tr. Eg.
	6	12	"	I	*Sh. Eg.
28	12	15	"	I	Oc. Dis.
	3	20	"	I	Ec. Re.
	7	32	"	III	*Oc. Dis.
	10	22	"	III	*Oc. Re.
	11	3	"	III	*Ec. Dis.
29	1	50	A. M.	III	*Ec. Re.
	4	58	"	II	Oc. Dis.
	9	16	"	II	Ec. Re.
	9	52	"	I	Tr. In.
	10	24	"	I	Sh. In.
	11	48	"	I	Tr. Eg.
	12	41	P. M.	I	Sh. Eg.
30	6	41	A. M.	I	Oc. Dis.
	9	49	"	I	Ec. Re.
	11	19	P. M.	II	*Tr. In.
31	1	5	A. M.	II	*Sh. In.
	1	56	"	II	*Tr. Eg.
	3	45	"	II	Sh. Eg.
	3	59	"	I	Tr. In.
	4	53	"	I	Sh. In.
	6	15	"	I	Tr. Eg.
	7	9	"	I	Sh. Eg.
Feb. 1	1	8	A. M.	I	*Oc. Dis.
	4	18	"	I	Ec. Re.
	9	26	"	III	Tr. In.

NOTE.—In., denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse. Oc., denotes occultation; Tr., transit of the satellite; Sh. transit of the shadow; * Visible at Washington.

Transit of Mercury, Nov. 10-11, 1894.—Instructions for observing this transit of Mercury were issued to observers in the United States generally, by the Naval Observatory, at Washington, D. C. Additional suggestions were sent out by Professor S. Newcomb, Supt. of the American Ephemeris and Nautical Almanac. The following reports have been received:—

Lowell Observatory, Flagstaff, Arizona.—Mercury began by being behind time. To Professor Pickering, who awaited at the six-inch his entrance on the solar disk, he failed to appear till a minute (by transmitted W. U. T.) after he was expected.

Ingress, exterior contact occurring at $3^h\ 57^m$ G. M. T.
instead of $3^h\ 56^m\ 2^s$ G. M. T.
and Ingress, interior contact occurring at $3^h\ 58^m\ 40^s$ G. M. T.
instead of $3^h\ 57^m\ 46^s$ G. M. T.

The usual phenomena were all more or less visible and all more or less palpably due to any cause but Mercury. In detail they were as follows:

After having delayed, partly from irradiation, partly from the present imperfection of his theory, from appearing on time, he further clung to the sky. Professor Pickering observed, in the manner noted by Huggins in 1868, the planet assuming when a little more than half way on the shape of a beehive, irradiation destroying the solar cusps entirely. Professor Pickering saw no aureole just before interior contact, such as has been observed in the case of Venus.

When fully on he appeared to me perfectly round and decidedly darker than the sun-spots, in about the proportionate intensities of Forster's estimate of 1848, that is 8 to 5. With an ordinary eye-piece, power 180, and two pieces of glass one red, the other green, used together, both Professor Pickering and I saw a bright halo surrounding the planet which we each attributed unhesitatingly to contrast. With a solar eye-piece and an ordinary eye-piece, power 200, capped with the usual dark glass cap, the halo was not visible, but Professor Pickering observed it again when the two pieces of dark glass were substituted for the usual cap. These were much darker than the cap as the Sun could be well scanned by the naked eye through them while the glare was too great through the cap.

On the planet's disk I imagined a tiny bright speck, *s. f.* which very obligingly turns out to agree with Jenkins' formulæ. But I think I remember several other specks—Professor Pickering also saw similiar imperfections, which we neither of us were in the least inclined to impute to Mercury. Professor Pickering made every attempt to see the so-called diffraction spot first by looking for it in the usual way and then by maltreating the instrument in every conceivable manner, by diaphraming it down to 2.3 inches aperture, then to 1 inch, and finally unscrewing the lens unequally on the sides, but was quite unsuccessful in making it accomplice to any evil result.

Throughout I noticed that the planet's disk was fringed internally by a penumbra of ray-like character resembling the penumbræ of sunspots, which extended in equally on all sides to about two-fifths of the radius. It was visible under all instrumental and atmospheric conditions. Professor Pickering also saw this but to him it seemed like a light, hazy band extending in to the same distance. He attributes it to superposed images of the planet's disk; to me it appears probably to be an interference effect.

Photographs of the planet in transit were taken at my suggestion by Mr. Douglass. They are of the usual excellence of photographs of the planets and enable anyone of sufficient faith to make out an impression on the plate of Mercurial appearance, when it has once been pointed out to him.

Mercury at Egress.

At egress I noted a curious series of irradiation effects. The beehive aspect was assumed in due course, and when about two-thirds off the disk of the sun, the planet put out a couple of appendages, one on either side, like small wings, peculiarly appropriate to Mercury, shown in the accompanying sketch. Thus prepared, the planet took flight into space at $9^h\ 13^m\ 5^s$ G. M. T., or like his entrance from it, late. PERCIVAL LOWELL.

Lowell Observatory, Nov. 12, '94.

Davidson Observatory, San Francisco, California.—I herewith inclose you the results of observations on the the transit of Mercury, Nov. 10, 1894, by Messrs. Fremont Morse of the United States Coast and Geodetic Survey and Chas. B. Hill formerly of the Survey and later of the Lick Observatory.

My own results were unsatisfactory and I will not publish them. We were fully prepared for the early observations ($7^h\ 46^m$ A. M.) and had a free horizon, but unfortunately we were on the wrong side of the dense fog.

The best seeing we had was when the fog was thinning and before the atmosphere became very unsteady.

During the progress of the transit I looked many times at the planet through

both the Fraunhofer telescopes, and on one occasion in the telescope Mr. Hill was using I saw a very faint whitish aureola around the planet, fully a diameter of the planet in breadth and not brightest in contact with the planet; and also a very faint, whitish, nebulous centre on the planet.* It was the first time I had seen such a phenomenon in transits of Mercury or Venus; and I changed my position several times to be sure of the exhibition. I attributed it to the atmospheric conditions: the air was very unsteady at times, and there was little or no wind.

I observed the meridian passages of the Sun and planet in the transit instrument.

GEORGE DAVIDSON.

Observations of Chas. B. Hill.—I used the "Fraunhofer" telescope, on tripod stand, aperture 3 inches, power about 120 diameters, and with a deep red shade glass. Sidereal chronometer No. 1739 used in these observations was 5.1 secs. slow of local sidereal time, as determined by comparisons before and after contact with the standard chronometer of the U. S. Coast and Geodetic Survey Observatory.

In the morning a dense fog prevented all possible chance of obtaining contacts I and II. At egress the sky was clear, but the atmosphere was very unsteady, and the contacts were observed as well as the conditions would permit, but not very satisfactorily. The instants as noted by the chronometer were:

III.	16^h	21^m	20^s	"not yet"
	16	21	40	"not yet"
	16	21	51?	contact
	16	22	03	past.
IV.	16	23	22	doubtful
	16	23	31	gone

Assuming that the instant marked "contact?", and the mean of the two last times recorded, represent respectively the best values of III and IV to be obtained from these observations, and reducing to Pacific Standard Time, we have

III. $1^h\ 11^m\ 36^s.8$
IV. 1 13 12. 1 P. M.

Davidson Observatory, Nov. 17th 1894.

CHAS. B. HILL.

Fremont Morse Observations.—Fog prevented the observation of the I and II contacts, and I did not go to the Observatory until about an hour and a half before the end of the transit.

The instrument used was one of the large reconnoitering telescopes of the Coast and Geodetic Survey, having an aperture of 3 inches, and a power of 105. A dark yellow glass gave a very satisfactory shade, the image of the sun being neither too bright nor too dark.

The atmosphere was unsteady, but with the low power used the disturbance was not so great as to cause much trouble.

The recorded and reduced times are as follows:

Contact.	Time by Chro. 5638 M. T.			Chro. fast of Pacific Standard Time.			Pacific Standard Time of Contacts.		
	h	m	s	h	m	s	h	m	s
III	1	20	15.5	0	08	42.6	1	11	32.9
IV	1	22	01.0				1	13	18.4

FREMONT MORSE,
Assistant Coast and Geodetic Survey.

Davidson Observatory, Nov. 19, 1894.

* I think Dr. Huggins has recorded a similar phenomenon.

Halsted Observatory, Princeton, N. J.—The weather permited us to do nothing except to observe the two contacts at *ingress*. At egress the Sun was hidden, and during the time the planet was on the Sun it was so generally overcast that no micrometrical or spectroscopic observations were even attempted.

At the Halsted Observatory with the 23-inch telescope the observations were made by myself—external contact at $10^h\ 56^m\ 39^s$, and internal (breaking of black ligament) at $10^h\ 58^m\ 22^s$. At the School of Science Observatory with the 9½-inch telescope Professor Reed noted the external contact as already obvious at $10^h\ 56^m\ 46^s$; and the internal at $10^h\ 58^m\ 25^s$. We both observed through thin clouds.

C. A. YOUNG.

Agricultural College, Brookings, S. D.—President Lewis McLouth observed the transit using a five-inch glass, power 240. A full report was given with drawings showing several positions of the planet near egress. No black drop was seen, the planet and limb of the Sun were very clear and distinct. The times of contacts were:

	Central Standard Time.		
Second interior contact	3^h	11^m	18^s
Bisection of planet	3	12	23
Second exterior contact	3	13	02

Chabot Observatory, Oakland, California.—The third and fourth contacts of the transit, were observed with 8½-inch equatorial, power 200. The other two were lost by fog. The seeing was 3 on a scale of 5 at 3d contact, but very poor at 4th, making it uncertain by 3 or 5 seconds:

	Standard Pacific Time.
Third contact	$1^h\ 11^m\ 39^s.0$
Fourth contact	1 13 18 .5

Charles Burckhalter was observer.

Leander McCormick Observatory, University of Virginia.—Professor O. Stone reports observations with 4-inch Kahler equatorial, power 110 diameters. Edgar Odell was observer, eye and ear, with chronometer.

	Eastern Standard Time.			
	h	m	s	
I	10	56	59.5	
		58	31.0	Mercury's disk still not circular.
			33.5	Ligament one-fourth diameter of Mercury.
			37.5	Drop nearly square.
II	10	58	{45.0	Minimum drop
			{47.0	Circle of light complete.
III	4	11	12.5	Geometrical contact.
IV	4	12	55.5	

Definition for I and II good; not a cloud in the sky. Definition for III and IV poor; Sun came out through a rift in heavy clouds just long enough to observe the contacts.

Dearborn Observatory, Evanston, Ill.—Professor Hough reports an observation of the second contact at a break in clouds for a few seconds. The Central Standard time as recorded by his printing chronograph was:

$9^h\ 58^m\ 26^s.4$.

Smith Observatory, Beloit College.—Professor Chas. A. Bacon could get no observation on account of clouds.

Washburn Observatory, Madison, Wisconsin.—Professor G. C. Comstock says, we suffered from a blizzard all day on the 10th.

Mount Holyoke College, South Hadley, Mass.—Elizabeth M. Bardwell first saw the Sun at one o'clock. Mercury was black on Sun's disc. Clouds prevented observations of contacts.

COMET NOTES.

Rediscovery of Encke's Comet.—Encke's periodic comet was discovered on its return by Cerulli at Teramo on Nov. 1. Its position Nov. 4, Berlin noon, was: R. A. $23^h\ 8^m\ 8^s$; Decl. $+\ 13°\ 36'$. Its daily motion was $-\ 2^m\ 16^s$ in R. A. and $-\ 16'$ in declination. Owing to bad weather we have not yet looked it up at Northfield. The latest Ephemeris at hand extends only to Nov. 8 so that we are unable to indicate its course during December. On Nov. 8 it was in R. A. $22^h\ 59^m\ 30^s$; Decl. $+12°\ 32'$, and moving slowly southwest; this is in the southern part of the constellation Pegasus.

Discovery of a New Comet.—A very faint comet was discovered by Edward Swift in California Nov. 20.500 in R. A. $22^h\ 18^m\ 24^s$, Decl. $-\ 13°\ 07'$. Its motion is slow easterly. It is in the constellation Aquarius.

The next return of Comet 1884 II (Barnard).—In *Astronomische Nachrichten* No. 3260 Dr. Berberich gives the following elements of this comet for the epoch 1895, Feb. 9.0, Berlin mean time:

M	$= 339°\ 07'\ 39''.3$		
ω	$= 300\ 58\ 44\ .6$	ω	$= 300\ 58\ 55.3$
ν	$=\ 5\ 13\ 01\ .4$ 1890.0	ν	$=\ 5\ 21\ 13.2$ 1900.0
i	$=\ 5\ 27\ 35\ .7$	i	$=\ 5\ 27\ 40.3$
φ	$=\ 35\ 42\ 44\ .7$		
μ	$= 656''.252$		
$\log a$	$= 0.488624$	Perihelion passage June 3.5 Berlin M. T.	

The time of perihelion passage is uncertain by about $\pm$ 8 days. Dr. Berberich gives a search ephemeris extending from April 24 to July 5. The theoretical brightness of the comet in May, 1895, will be about twice that which it possessed when last seen in 1884, the maximum being reached in June.

PRACTICAL SUGGESTIONS

83. (1) In the formula, $F = k\dfrac{M_1 \times M_2}{d^2}$ "Young's General Astronomy," page 109, line 10 from the top, what is k? Is it in the case of the Earth and bodies on its surface 16½ ft. in one second at distance of its radius? And in case of torsion balance, is it one three hundred and sixtieth at distance of balls from each other? Or is it half one three hundred and sixtieth.

(2) On the same subject, page 62 "Young's Elements of Astronomy" it is stated that the stress has the product of the masses of two bodies in its numerator and the acceleration has the sum. Acceleration then does not differ between pairs of bodies in same ratio as stress but in a far less degree.

(3) In case of the torsion balance, is one three hundred and sixtieth to be multiplied by the product of the masses of the balls? H.

Answer: (1) In the formula referred to, viz.: $F = k \frac{M_1 \times M_2}{d^2}$, "$k$" is not "$g$" nor any quantity which is peculiar to the Earth, it is the so-called "Newtonian constant" or the "constant of gravitation;" a "constant of nature" which like the chemical equivalent of an element, or the wave-length of a given ray of light, is believed to be the same throughout the whole material universe. It is the force with which two masses of one unit each would attract each other at a distance of one unit, and its numerical value depends upon the units of force (stress), mass and distance which are used. On the C. G. S. system, in which the unit of stress is the "dyne," while the units of mass and distance are the gramme and centimetre respectively, its value is 0.000,000,066,576 + according to the most recent experimental determination by V. Boys. The dyne is 1/981 of the *weight* of a gamme at Paris. "k" has nothing whatever to do with any of the conditions of the "torsion balance" experiment.

(2) Certainly not. But it is worth noting that in the passage referred to, it should be stated that in the C. G. S. system of units the "k," of the Acceleration-equation is identical with the "k" of the Stress-equation.

(3) No. In the case of the torsion balance if we denote by "q" the torsion a co-efficient of the apparatus, and by "D" the angular deflection produced by the attraction between the small balls and the large ones, then "f" is simply $q \times \frac{D^\circ}{360^\circ}$, half of it acting at each end of the bar. According to the law of gravitation this must of course also equal $k \times \frac{B \times b}{d^2}$, so that from the torsion balance experiment the value of "k" can be determined as well as the mass of the Earth.

84. What is the best method of cleaning a diffraction grating? H.

Answer: The question asked by Mr. H. is a very important one. And I am glad that I am in a position to answer it. Professor Hale informed me some months since that a German physicist discovered that *strong ammonia* is much superior to carbon bisulphide, which I have always used in the past for cleaning gratings. I have tried the ammonia on a number of very badly soiled gratings and find it works splendidly.

In cleaning a grating use a piece of very soft clean chamois. First brush off dust particles with a camel's hair brush, then having saturated a corner of the clean chamois with ammonia, rub the surface of the grating with some pressure, as nearly as possible *in a direction parallel to the ruled lines.* After going over it carefully a few times, wipe dry with a soft, smooth part of the chamois. Never use the outer or irregular edge of a chamois as it often contains nodules of lime. Prepared chamois may be purchased, but any one can prepare a chamois by washing it in soap and water, rinsing it in clear water, squeezing the water out as far as possible, then dry it gently before a fire—*rubbing it together constantly* while it is drying. It is a rather tedious job, but it pays—and is the only way I know of to have the chamois *soft* after washing. It should then be put away in a safe place to keep it free from dust. I find an ordinary glass fruit jar with a gum ring under the screw top excellent for this purpose.

The metal of a grating, though hard and brittle, is softer than crown glass. If it were not that it is so easily stained by foreign matter getting on it I would recommend the same process of cleaning as for objectives, but they will get stained. And some people have a *penchant* for putting their fingers on a grating surface as

"it *feels* so beautiful," while others will blow the dust off for you sending at the same time a spray of spittle on the surface that does a thousand times more harm than dust. Oh that we could send such good people to some other planet where they don't know how a delicate optical surface must be made and cared for to do its best work.

May I add to the above advice that it is almost *wicked* to be constantly rubbing a grating surface. *Clean it only when it is needed*, and use good sense as to when it is really necessary. J. A. B.

85. For the second time I have been asked by one of the members of The Astronomical and Physical Society of Toronto to say whether the times given in the *Ephemeris* and POPULAR ASTRONOMY for the occurrence of the eclipses, etc., of the satellites of Jupiter, are meant for "the beginning, middle or ending of these phenomena." I have promised to submit the matter to POPULAR ASTRONOMY.

While on this subject, permit me to refer to a phase which has presented itself to me on many occasions while watching these phenomena. According to what telescopic power are they graded? For instance, I have been able, in my 10-inch reflector still to see a satellite long after it has vanished in a smaller telescope. Or, take the case of a transit. I have been many times able in the same instrument to see the sky between the Moon and the planet's disc, while, in a smaller glass, the Moon had disappeared apparently on the disc. It, therefore, occurred to me that there must be a standard—a standard, however, I have never seen mentioned anywhere. L.

Answer: In answer to Mr. L.'s query, I would say that the phases of the eclipses of Jupiter's satellites, as given in the *Ephemeris*, are supposed to be these:

The time of eclipse disappearance should be that at which the satellite would disappear from view in a telescope of the kind most in use a century ago. Eclipse reappearance gives the time when the satellite should reappear in such a telescope.

As these computations are made from the tables of Delambre, published more than half a century ago, the times now computed may vary appreciably from those corresponding to the supposed phase. The times are also doubtful by several seconds, from the possibility that the Earth has slightly changed its time of rotation since the times that the great body of observations were made on which these tables are based. N.

Nautical Almanac Office, Naval Observatory,
Georgetown Heights, D. C., October 29th, 1894.

GENERAL NOTES.

A number of the reports of the transit of Mercury are necessarily deferred to a later issue.

So much space is taken in this number with articles and transit reports that notes and queries can have little attention.

The attention of all our readers is called to our liberal offers for new subscribers to be found under the head of Publisher's Notices.

Some of the articles of this number contain the simple methods by which predictions of interesting phenomena are made. We think our readers will easily follow them.

The Central Tennessee School of Mechanical Engineering, at Nashville, Tenn., was totally destroyed by fire on the night of Nov. 3d having been set on fire by fire bugs who burned 15 other buildings in the immediate vicinity within a week previous. The contents of safe and vaults came through intact and all objectives, eyepieces and other instruments on hand belonging to customers are safe.

Six large equatorials complete were burned and a car load of small instruments in process of construction, one large 6-inch complete mounting went down that would have been shipped the following week, and two within ten days of completion. The plant was insured and Professor Sedgwick telegraphed for new machinery before the fire engines left the scene. He is now in the East selecting a new outfit complete and will be running in 30 days. All customers who have work in progress of completion will be patient as it will come a little later on.

Astronomical and Physical Society of Toronto, Canada.—Meeting of Oct. 16, 1894.—Dr. E. A. Meredith, chairman. A resolution of condolence with the relatives of Mr. Stephen Huebner, an active member lately deceased, was passed.

At this meeting Mr. Z. M. Collins presented two silver-on-glass mirrors, which he had ground, figured and polished himself, for reflecting telescopes. They were beautiful specimens of amateur instrument making. The diameters of these mirrors were four inches and six inches. Mr. Collins informed the members that he had followed essentially the method described by the late Dr. Henry Draper; also, he was indebted for some valuable hints regarding the silvering to Dr. J. A. Brashear, of Alleghany. Dr. J. J. Wadsworth, of Simcoe, Ont., had been consulted as well, that gentleman having achieved success in the figuring of mirrors for reflectors. Mr. Collins' six-inch mirror has been tested by all the methods known to the practical optician, and has been proved to be of true parabolic figure, so that it is to be mounted and prepared for work on the approaching transit of Mercury.

Mr. Andrew Elvins read a clever and exhaustive paper on meteorology, which finished the evening.

JOHN A. COPELAND.

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Vols. 16, 17 and atlas, Cordoba Durchmusterung. Brightness and position of every fixed star down to the tenth magnitude, comprised in the belt of the heavens between 22 and 42 degrees of south declination for the mean equinox of 1875.0, 2 vols., 4to and folio atlas, containing 12 maps. Buenos Aires, 1892-94. $28.75.

FLAMMARION (C.) POPULAR ASTRONOMY: A general description of the heavens, translated by J. E. Gore, with 3 plates and 288 engravings. 8vo., cloth, 1894. $4.

LOHSE (O.) Planetographie, with 15 engravings. 8vo., cloth, 1894. $1.

PRINZ (W.) Agrandinements de photographies lunaires. Mare Imbrium, Bullialdus, Copernicus. 3 plates, 20 × 26 in. 1894. $1.15.

SPITALER (R.) Bahubestimmung des Kometen. 1851, III (Brorsen). 4to. 1894. 50 cents.

STONEY (G. J.) On a mounting for the specula of reflecting telescopes. Designed to remove the impediment to their being used for celestial photography and spectroscopy. 8vo. 1894. 40 cents.

These works can be furnished by Wm. Wesley and Son, 28 Essex Street, trand, London.

PUBLISHERS' NOTICES.

As a large number of subscriptions to POPULAR ASTRONOMY expire with the present number, the publishers ask the favor of renewal at an early date. Subscription blanks are enclosed for the convenience of those whose renewal is due at this time.

The following suggestive letter has been received from a teacher of Astronomy in one of our largest cities. "As a large number of your subscribers are teachers of Astronomy, I suggest that with each issue of the journal you send to one or more of them a sufficient number of copies for distribution among the members of their classes. The excellent maps which you are publishing from Poole Bros. Planisphere furnish the best means with which I am acquainted for finding and locating the constellations, and this feature alone cannot fail, I think, to interest young students in the journal, and awaken new interest in the study of Astronomy. I have three classes in Astronomy, each containing thirty members. If you think well of the suggestion and will send me thirty copies of the November issue, I will try the plan with one of my classes." This letter interests us much, and we shall be glad to test the plan suggested by sending sample copies, at a nominal price, to a dozen different schools. The expense involved prevents our making the offer to more. If you are interested in the matter let us hear from you.

This magazine, in attempting to meet, in the best way, the wants of the student and amateur world as well as of the popular reader, has been materially aided by its friends. Many have sent the names of new subscribers, many more have sent addresses of persons interested in Astronomy, who, through a sample copy, have become subscribers. Members of Astronomical Societies and editors of papers have, in a generous way, extended the knowledge of the publication. Men who are carrying on a large correspondence have asked for a supply of our circulars that they might enclose them in the letters which they are sending out. In these and other ways a strong support has been given. These favors we acknowledge, and ask their continuance that we may find it financially possible to carry out the larger plans for the publication.

POOLE BROTHERS NEW MAP OF THE MOON.—We have thought the new Map of the Moon, first published by the Poole Brothers, of Chicago, a work of so much merit that we are anxious to get it before the readers of this periodical. If it could be examined, we believe every teacher of Astronomy of the High School, Academy or College would want a copy, to aid in instruction pertaining to one of the most interesting members of the solar family. We have thought of a way to make it comparatively easy for anyone to obtain a copy of this fine new map and its accompanying indexes, and that is to offer it as a premium for subscribers to POPULAR ASTRONOMY.

We, therefore, make this offer:

1. Any new subscriber, sending us $3.00, will be entitled to one copy of the Map and Index and POPULAR ASTRONOMY for one year.

2. Any old subscriber, sending us two new subscribers (at $3.00 each) and $1.00 additional, will secure for each of the new subscribers one copy of the Map and Index and POPULAR ASTRONOMY for one year; and will secure, also, one copy of the Map and Index for himself,

This very favorable offer is an experiment, and we are not sure that it will be continued long, because of the considerable expense involved by all the parties who have been interested, to try it.

The publisher of ASTRONOMY and ASTRO-PHYSICS desires to secure, by purchase or otherwise, thirty (30) copies of the January number (1894), of that publication. Forty cents a copy will be paid to anyone who will furnish one or more copies of that number, in perfect condition.

ASTRONOMY AND ASTRO-PHYSICS, Volumes XI (1892), XII (1893), XIII (1894), contain, each, nearly one thousand pages of current Astronomy for the respective years to which they belong. They furnish an ample review of modern Astronomical progress. These volumes, in pamphlet form, one or all, may now be obtained at $4.00 per volume.

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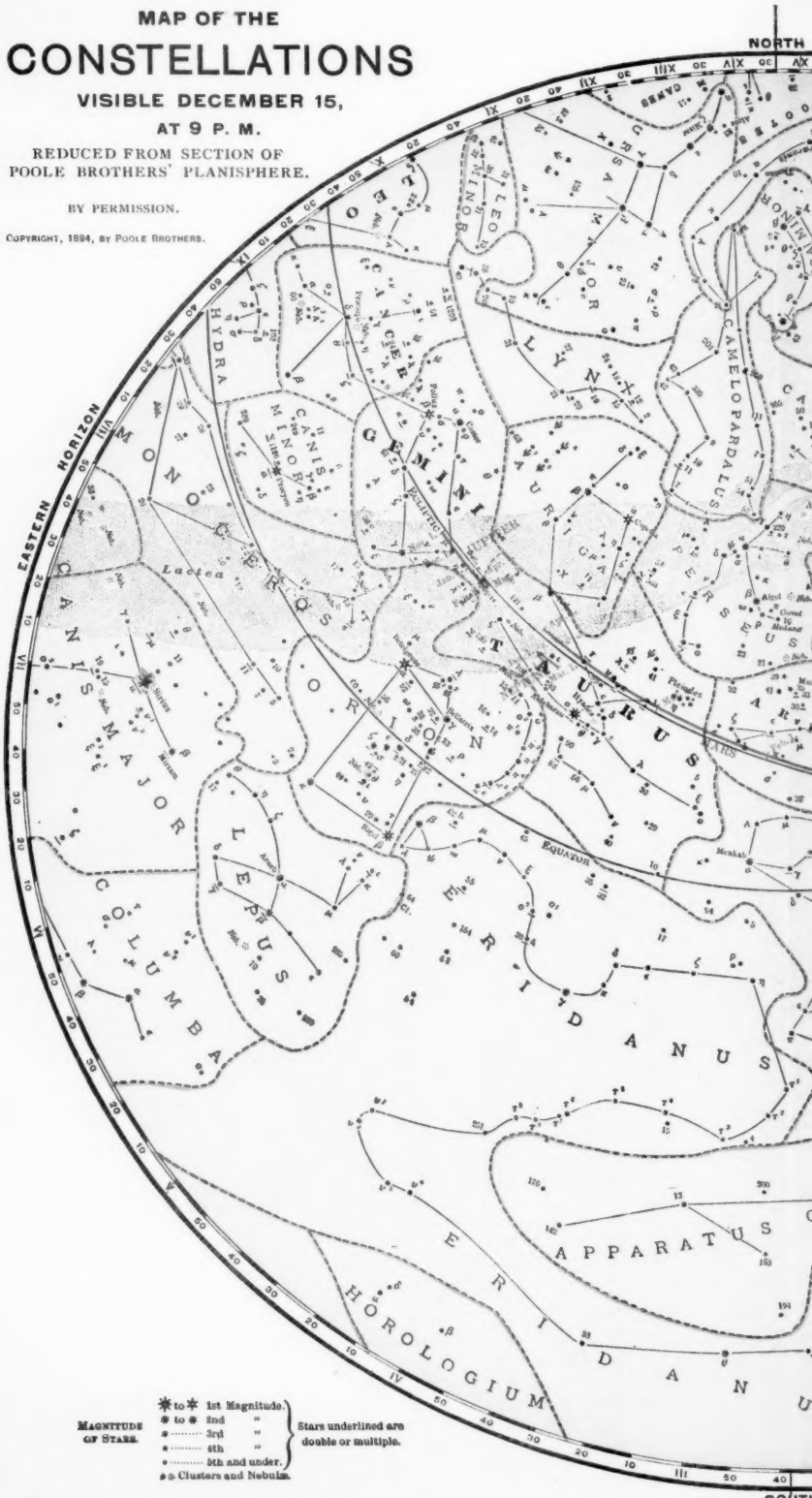
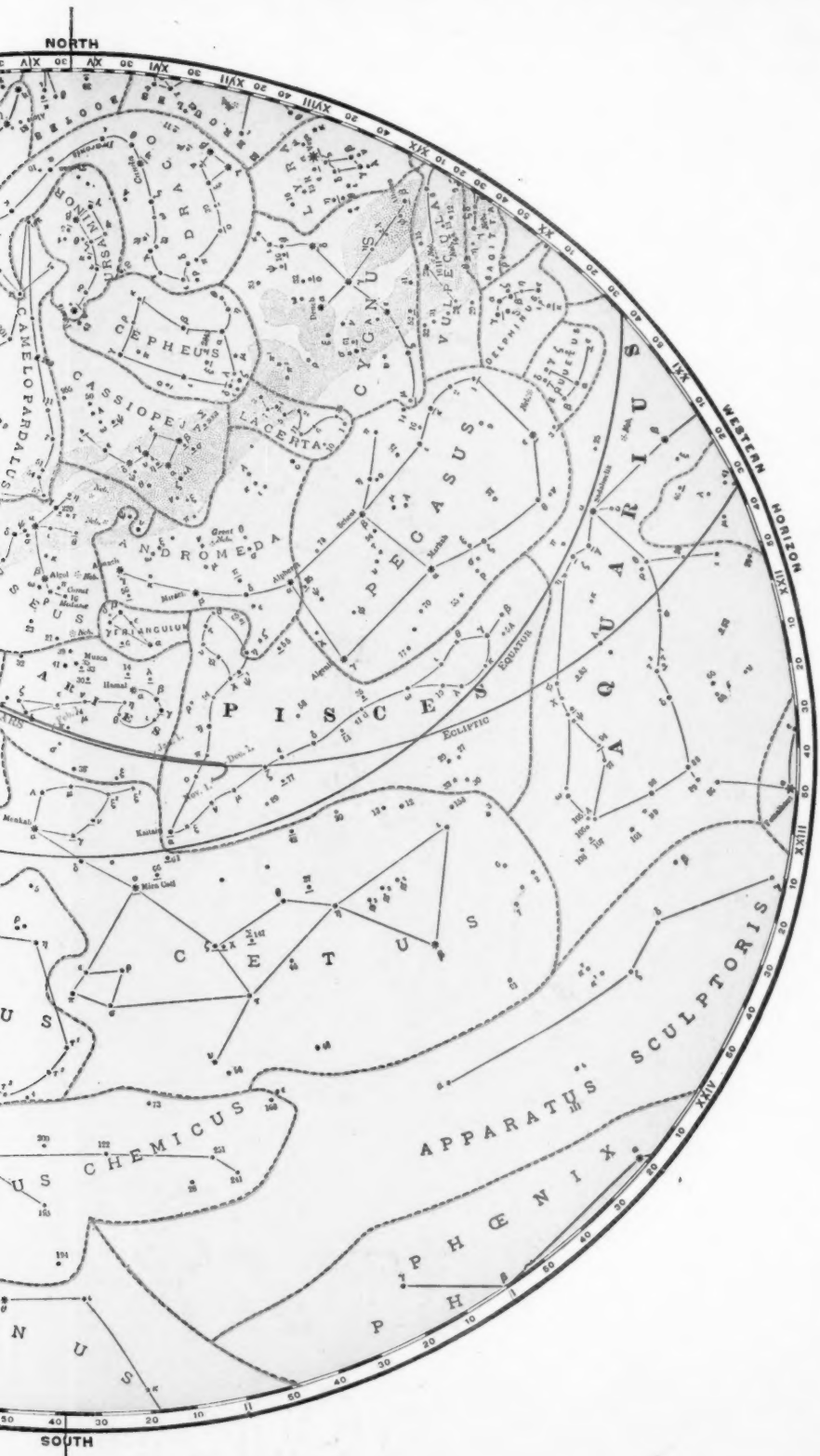


MAGNITUDE OF STARS.

✱ to ✱	1st Magnitude.
✱ to ✱	2nd "
✱	3rd "
✱	4th "
✱	5th and under.

Stars underlined are double or multiple.

✱✱ Clusters and Nebulæ.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